S. Hrg. 100-3

OZONE DEPLETION, THE GREENHOUSE EFFECT, AND CLIMATE CHANGE

JOINT HEARING

BEFORE THE

SUBCOMMITTEES ON
ENVIRONMENTAL PROTECTION
AND
HAZARDOUS WASTES AND TOXIC SUBSTANCES

OF THE

COMMITTEE ON
ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE

ONE HUNDREDTH CONGRESS

FIRST SESSION

JANUARY 28, 1987

PART 2

Printed for the use of the
Committee on Environment and Public Works

U.S. GOVERNMENT PRINTING OFFICE

70-303 WASHINGTON : 1987

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

S321-5

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OZONE DEPLETION, THE GREENHOUSE EFFECT, AND CLIMATE CHANGE

WEDNESDAY, JANUARY 28, 1987

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
SUBCOMMITTEES ON ENVIRONMENTAL PROTECTION AND
HAZARDOUS WASTES AND TOXIC SUBSTANCES,
Washington, D.C.

The subcommittees met, pursuant to notice, at 9:30 a.m., in Room SD-406, Dirksen Senate Office Building, Hon. George Mitchell (chairman of the Subcommittee on Environmental Pollution) presiding.

Present: Senators Mitchell, Baucus, Burdick, Mikulski, Reid, Chafee, Stafford, Durenberger, and Pressler.

Also present: Senator Gore.

OPENING STATEMENT OF HON. GEORGE J. MITCHELL, U.S. SENATOR FROM THE STATE OF MAINE

Senator MITCHELL. Today's hearing is a combination of two separate hearings originally scheduled by me, as chairman of the Environmental Pollution Subcommittee, and by Senator Baucus, Chairman of the Hazardous Wastes and Toxic Substances Subcommittee, but due to last week's weather, we combined the hearings.

I thank the witnesses originally scheduled to testify last Friday for agreeing on such short notice to rearrange their schedules and appear here today. Since four of the six witnesses are from out of town, this is no minor inconvenience. I appreciate their efforts and look forward to hearing the testimony.

I originally scheduled last Friday's hearing to focus on the greenhouse effect and global climate change. This committee has had several hearings on the greenhouse effect and ozone depletion, and it is the intention of the members of the committee to continue to investigate this serious global problem.

Our interest is not theoretical. It is a real and practical concern for the condition of this planet within our lifetimes. Many of us in policy-making roles are used to hearing scientists respond cautiously when asked to make predictions about the future. On the question of global climate change, however, there is a surprising and discouraging consensus. The greenhouse effect is not a mathematical model, but a real phenomenon. Witnesses today will testify that our process of industrialization has spewed such high quantities of greenhouse gases into the atmosphere that our global climate is changing.

It is not just a handful of scientists and politicians awakening to this problem. A review of recent publications demonstrates that the concern is widespread. For example, in June of last year, the Electric Power Research Institute, EPRI, published an editorial and a feature article on the greenhouse effect, stating that "the sweeping consequences of accumulating greenhouse gases in the atmosphere may turn out to be the greatest environmental problem of modern times."

The November 24, 1986, edition of Chemical and Engineering News, published by the American Chemical Society was a special issue on "The Changing Atmosphere." An editorial in that publication had the headline: "The sky is falling, maybe for real."

The December, 1986, copy of the EPA Journal stated on its cover "Our Fragile Atmosphere: The Greenhouse Effect and Ozone Depletion," accompanied by a photo of Casco, Maine. The journal contained ten articles on the problem of global climate change and ozone depletion.

This is in addition to a segment on "NOVA" and numerous other newspaper articles. The message contained in all these articles is summarized well by EPA Administrator Lee Thomas, who wrote,

> . . . the nature of both ozone depletion and global warming are such that if we wait until health and environmental impacts are manifest, it might be too late to take adequate steps to address these problems. We must realize that there will always be scientific uncertainty associated with these complex problems. We will have to be prepared to act despite these uncertainties.

Witnesses today will testify that the areas of uncertainty continue to shrink. Mounting evidence demonstrates that we are running out of time more quickly than previously believed. From a policy perspective, this means that we must make climate change and ozone depletion a priority. Testimony today will describe the links between these and other pressing air pollution problems, such as acid rain.

We are already committed to change. We have emitted so many million tons of greenhouse gases, such as carbon dioxide, methane, chlorofluorocarbons, and others, that we are already committed to a warming of the atmosphere, even if we suddenly stopped emitting all greenhouse gases tomorrow. We have already seen the Franz Joseph Glacier in New Zealand retreat significantly in the last 50 years. So the question is not if change will occur, but how much?

Scientists agree that with current estimates of fossil fuel use, the primary source of carbon dioxide emissions, the average global surface temperature will increase between two and eight degrees Fahrenheit by the middle of the next century. This estimate is based on carbon dioxide emissions alone, and does not take into account CFCs, methane and other greenhouse gases which some predict may account for up to 60 percent of the global warming.

While an increase in temperature is an appealing thought to some in the middle of winter, a global warming trend would not simply make cities like Washington warmer. A warming of the magnitude being predicted has not occurred since man first walked the earth. Of equal concern is the fact that the rate of change is unprecedented. We are changing the climate more in 120 years than it has changed in the previous 100,000 years.

As the planet heats up, basic weather patterns are disturbed. Leningrad may become significantly colder, as Bismarck, North Dakota, becomes unusually warm. These extremes are wholly consistent with a sudden warming of the globe and the climate change it induces. Scientists cannot yet tell us what the regional effects will be, but the pace of change suggests that any effect will be sudden and potentially overwhelming to plants and animals.

A sea level rise due to melting of the polar ice caps would be devastating to coastal states such as Maine. Our agriculturally productive Midwest would become parched, while southern California could find itself experiencing regular flooding. It is these kinds of dramatic and potentially catastrophic changes that we may be facing in the near future.

Witnesses today will explain the nature of the ongoing changes and their implications. They will address the issue of timing. To how much change are we already committed. They will discuss the global temperature record and the historic record of climate and describe for us how this data fits into the anticipated climate change. Finally, we will examine the policy questions that the data presents.

A problem of this magnitude demands a carefully considered response. What can we do? Reducing our CO_2 emissions would clearly be a step in the right direction. Two of our witnesses today will discuss available options, such as improved conservation and efficiency and increased use of natural gas, which emits less CO_2 per unit of heat.

Even if the United States were to achieve dramatic CO_2 reductions, this would not be enough. The United States and the Soviet Union between them have 75 percent of the world's coal reserves. China is ranked third, and with that nation's industrial expansion, it is a major source of CO_2 emissions.

Since international cooperation is essential, I will press for an adequate U.S. contribution to the United Nations Environment Programme, or UNEP. This Administration repeatedly has attempted to eliminate or dramatically reduce our share of funding for UNEP, but this organization is critical in developing international cooperation on issues such as global climate change.

Second, I urge the World Bank to consider emissions of greenhouse gases such as CO_2 when financing investments related to energy supply and use in developing countries. Control of CO_2 by the United States can be offset by other nations interested in building their own industrial capabilities. These countries should not be discouraged from developing their own technology for sustenance and trade, but consideration should be given to worldwide CO_2 emissions.

The United States cannot urge upon others what it does not do itself. In this country, there is a strong desire for further controls on chlorofluorocarbons, which are both greenhouse gases and the cause of much ozone depletion. While such controls are essential, we still must face the problem of how to control other major greenhouse gases.

In a later hearing of the Environmental Pollution Subcommittee, I expect to explore Federal research and policy activities in detail

and delineate what changes are necessary within the Federal Government to effectively address this problem.

Greenhouse gases and their effect on global climate change present a difficult problem for policy-makers. Changes necessary to avoid climate change may be dramatic, on a national and international scale. It would be much easier to wait and respond only after the floods and droughts began, but we cannot afford to wait, for if we wait long enough to see the full impact of global climate change, we will have waited too long to prevent it.

While man is adaptable, he is not infinitely adaptable. The earth's life support systems are at stake. We in government, business, and science must work together to demonstrate that we can anticipate and prevent disaster. Senator Chafee.

OPENING STATEMENT OF HON. JOHN H. CHAFEE, U.S. SENATOR FROM THE STATE OF RHODE ISLAND

Senator CHAFEE. Chairman Mitchell, and Chairman Baucus: It is both significant and fitting that the subject of our first hearing this year is the greenhouse effect, ozone depletion, and global climate change. You are to be congratulated for scheduling this hearing and signaling to all who follow the work of the Senate that the November, 1986, elections did not change the commitment of this committee to continue what we began last year.

As I learn more about these issues and the problem of man-made chemicals destroying the ozone layer, I become more convinced that man—through ignorance, or indifference, or both—is irreversibly altering the ability of our atmosphere to perform basic life support functions.

This is not a matter of Chicken Little telling us the sky is falling. At our hearings last summer, we heard graphic, powerful, and disturbing testimony from a number of distinguished scientists. Their testimony can be found in the hearing record numbered 99-723.

What did we learn from those hearings?

First, current predictions are that the greenhouse effect will increase the global average temperature by 1.5 to 4.5 degrees centigrade by the year 2030; that is about three to nine degrees Fahrenheit in little more than 40 years. Compare this to the fact that the earth's climate has not varied by more than one or two degrees centigrade in the past 10,000 years. Thus, the warming expected in the next 40 to 50 years will exceed any climatic change experienced in human history.

Second, "global average temperatures" disguise what can happen locally in different seasons. An average temperature rise of only three degrees centigrade could mean increases of more than ten degrees centigrade at high altitudes in some seasons.

Third, rainfall will be affected. Overall rainfall would increase, with temperate winters being wetter, but summers would be drier. This is an important point. The greenhouse effect is not simply a matter of higher temperatures. Storm patterns change. Extreme events are expected to increase. Summer droughts and snow storms might be worse.

What does these changes mean? What are the effects?

The most obvious effect of climate change will be on agriculture. Changes in agriculture will, in turn, produce a number of effects throughout society, altering the economic viability of farming, agricultural employment, commodity prices, and patterns of world trade.

There will also be widespread changes in natural ecosystems, with grassland and desert areas expanding and forested areas shrinking and moving towards the poles. This could have devastating consequences for nature reserves, including parks and wildlife refuges.

A warmer climate might make some cities unbearably hot.

The predicted climate changes also have major implications for water use and long-term planning.

Finally, as the oceans expand, sea levels would rise, causing flooding of low-lying areas.

The scientific evidence and the international consensus is that we have a problem, a serious problem. This could well be the most important and difficult environmental problem facing our generation. So the question is: What do we do about it?

At the last set of hearings, I called for a number of new initiatives. In addition to announcing that those initiatives received the active, bipartisan support of Senators Mitchell, Baucus, Stafford, Durenberger, Gore, Leahy, and Humphrey, I would like to give a brief progress report.

First, in response to our request, EPA's Administrator, Lee Thomas, has agreed to conduct studies of policy options and the effects of climate change. The policy study will develop options which, if implemented, will stabilize the level of greenhouse gases in the atmosphere. The effects study will help alert people to the risks of failing to take action and of allowing the rapid build up of greenhouse gases to continue. We don't need EPA to conduct another scientific assessment of the greenhouse problem, that has been done by numerous agencies, international organizations, and independent scientists. What we have asked EPA to do is policy and effects studies, not additional scientific assessments.

I am pleased to report EPA's willingness to do these studies. However, I am troubled by the fact that EPA has failed to provide the committee with the detailed work plan that was promised in a letter dated December 8, 1986.

Second, to provide a range of opinions, similar studies have been requested from the Congressional Office of Technology Assessment.

Third, at the June hearings, I urged the United Nations Environment Programme to consider bringing the nations of the world together to negotiate a treaty to limit greenhouse gases. A process similar to that being used to negotiate an agreement on depletion of the ozone layer would be useful. Since that time, I have met with UNEP's Executive Director, Mostafa Tolba, and was encouraged by his response and interest in the suggestion.

The U.S. Department of State, EPA, NASA, and other agencies are expected to cooperate fully in working with UNEP on these problems. With respect to UNEP funding, it will be important for Members of Congress to determine the appropriate level of U.S. funding on the basis of the merits of the program and not solely on the basis of the Administration's budget proposal.

Fourth, we called upon the President's Council on Environmental Quality to improve the government's responsiveness to these problems by alerting Federal agencies that they have a legal obligation to address these issues as part of the NEPA EIS process. We have not yet received a satisfactory response to that request but will continue to press the matter.

Finally, we have urged Secretary of State Shultz and Administrator Thomas to make sure that the greenhouse effect and climate change are on the agenda for meetings with the Soviet Union. Such discussions must take place at the highest levels of government and I will continue to pursue the matter. We must recognize that our two countries have a unique responsibility to address the build up of greenhouse gases. Together, the U.S. and the USSR produce almost 40 percent of the world's CO_2.

On December 10, 1986, I was honored to address the U.S.-USSR Joint Symposium on the Comprehensive Analysis of the Environment. At that meeting, I proposed that our countries undertake a joint effort to look at policy options for dealing with the greenhouse effect. It is my hope that such an effort can be launched in the near future.

It is encouraging to see that the U.S. plans to send a team of scientists to the Soviet Union next month to discuss the ozone depletion issue and that, under the auspices of our bilateral environmental agreement, an effort is underway to conduct a joint study of the effects of climate change.

Mr. Chairman, this hearing is important for several reasons. In addition to providing an opportunity to update the scientific information that we received last summer, it allows new Members of our Committee to become involved early in what for many of them will be totally new issues.

Not only does the greenhouse effect have severe global implications, but the effects closer to home are just as striking. Let us consider, for example, just the effects on new Members of our Committee.

Senators Breaux, Graham, Mikulski, and Warner, being from coastal states, should be particularly interested in the problem of sea level rise that will occur as part of the greenhouse effect. EPA estimates that, if uncontrolled, the greenhouse effect will cause sea levels to rise by one foot in the next forty years, and two to six feet in the next century. Considering just the effect on beaches, an increase in sea level of just one foot would wipe out between 100 to 200 feet of beach. That wouldn't leave much beach along the Atlantic or Gulf coasts. Many buildings would be lost. The destruction of coastal wetlands would be disastrous.

Similarly, I would expect Senator Pressler to be particularly interested in the implications that the greenhouse effect has for agriculture in this country. As stated in a recent United Nations Environment Programme draft report, the most obvious effect of climate change will be on agriculture. The area suitable for growing specific crops, such as wheat or corn, will move toward the poles. Our ability to produce crops in this country is threatened as never before.

Part of this hearing will help us to understand that there is a relationship between the greenhouse effect and other air pollution

problems, such as acid rain and ozone depletion. It should convince us that it is time to recognize carbon dioxide, chlorofluorocarbons, known as CFCS, methane, and nitrous oxide as pollutants.

The other part of this hearing will examine the role of the United States in the international negotiations that are going on to protect the ozone layer and to limit production of chlorofluorocarbons.

The United States went into the first round of negotiations with a good, sound position. The reluctance of our European and Japanese allies to fully cooperate in this area is deeply troubling. However, that reluctance on the part of the other countries during the first session is no reason to abandon, or even to weaken, the United States position.

Although the United States delegation had apparent agreement on three principles that formed the United States position, there appears to be some confusion as to what exactly is the United States position.

A November 5th paper from the State Department set forth the three principles for an international agreement: (1) a near-term freeze; (2) a long-term scheduled phase-out; and (3) periodic scientific review. This paper was sent to other governments in advance of the December negotiating session.

But then, when December rolled around, the U.S. position had already begun to slide backwards. The three principles were now general objectives. Instead of calling for a near-term freeze and scheduled phase-out of CFCs, our delegation called for agreement on (1) a meaningful near-term first step; (2) a long-term strategy and goals for coping with the problems; and (3) a carefully scheduled plan for achieving the long-term goals, including periodic reassessment.

The proposed text that was prepared by the U.S. had blanks in a number of critical areas and there was obvious disagreement among delegation members as to what those blanks meant. For example, is the 95 percent reduction to be achieved in five years or ten or 25 or even 150 years? Is the U.S. proposing that CFC emissions be reduced by 95 percent or is that number subject to negotiation to, say, 50 percent?

These are important questions. They are not just questions for this room, they are being asked by the other countries as well.

My concern is that the U.S. negotiating team does not know the answers and that, through unofficial channels and in the dark of the night, what was a sound U.S. position is being eroded in a totally unacceptable manner.

It must be noted that the responsibility for this matter rests squarely on the shoulders of the State Department and EPA. Other agencies can give advice but, unlike EPA, they have no legal responsibility in this area.

Our delegation's job is not just to produce an agreement. It must be a good agreement and, since the protocol will have to be ratified by the Senate, we will be the judge of what is a good agreement.

To assist our negotiating team, Senator Baucus and I have been working on legislation that will phase out harmful CFCs in this country. I plan to introduce at least one version of a bill in the next couple of weeks. That bill will include trade restrictions to

prevent other countries from taking advantage of unilateral U.S. action.

My preference is still to resolve this problem with an international agreement and I will not press for consideration of my legislation as long as I am confident that the international negotiations are going well, and that the U.S. team is committed to a near-term freeze and a scheduled phase-out that will take effect as soon as possible.

The importance of these issues is matched only by the complexity of them. But we have created complex problems before and we have responded to them with creative solutions. There is no reason to believe that the only answer is to throw up our hands and wait for the inevitable. The natural tendency is to say: this is too big for any of us to deal with.

Nevertheless, if we continue to press; ask tough questions; examine the policy choices; and put our best minds to work: I am confident that we can develop the necessary technologies. Nations that put men and women into space and develop sophisticated weapons that fly through the atmosphere or speed beneath the ocean's surface, should be able to channel that talent to solve the problems of atmospheric pollution.

Thank you very much, Mr. Chairman.

Senator MITCHELL. Thank you, Senator Chafee.

Senator Durenberger.

OPENING STATEMENT OF HON. DAVE DURENBERGER, U.S. SENATOR FROM THE STATE OF MINNESOTA

Senator DURENBERGER. Mr. Chairman, I would like to begin by congratulating you as you take the reins of the subcommittee. Having served as chairman of the subcommittee over the past four years, I can say that the job which the Senate has entrusted to this subcommittee is an important one and affords the chairman and members a tremendous opportunity to make a difference for the good of the nation.

Over the past four years the principal effort of the subcommittee was focused on reauthorization of the Safe Drinking Water Act which we finally achieved in June of last year. We also used the subcommittee to raise the issue of leaking underground storage tanks and passed legislation both to prevent future leaks and to correct those that have already occurred. Senator Stafford also allowed us to play a role in the new asbestos-in-schools abatement program. There were things on the legislative agenda which we didn't get to, like reauthorization of TSCA, but with drinking water behind us there may now be more of an opportunity to pursue those questions with the diligence they deserve.

As an oversight subcommittee, we also brought the issues of ground water contamination, biotechnology and pesticide residues on food supplies to the attention of the Committee. And about a year ago we held the Committee's first hearing on the subject we consider today, global warming and ozone depletion. I will have more to say on that directly. But before I do, I just want to wish Senator Baucus, a very brief, but very successful term as chairman of the subcommittee and want to assure him that I will do every-

thing I can to assist him with the legislative and oversight agenda he chooses to pursue.

Mr. Chairman, in taking on the subject of ozone depletion and the greenhouse effect in a legislative environment—in a subcommittee of the United States Senate—you have assigned the subcommittee a very difficult task. It is difficult for three reasons.

The first difficulty is the large uncertainty with respect to the magnitude and timing of the climate changes which the scientists are forecasting. It is very difficult to argue that significant changes in commerce or industry should be made, unless negative consequences of our current practices are clear and substantial. If it weren't for the hole in the ozone layer over the South Pole, I doubt that we would be gathered here today on this subject. And if it turns out that the ozone hole is the result of some phenomena other than CFC emissions, then I suspect that this issue will fall to the bottom of the agenda again and we won't be able to convince the Congress to take the time to pay attention until the middle of the next decade when the increase in the Earth's average temperature will have risen above the point of yearly variation. So the first difficulty is uncertainty. There is certainly a problem, but how big and when is still a puzzle.

The second difficulty is the international nature of the problem. In the field of environmental protection, we are almost in new territory here. It is global warming. And it will take a global solution. You can't legislate a solution from this room. In the late 1970s the United States, Canada and Sweden took the extraordinary step of banning CFCs in aerosol sprays. Although CFC production took a signficant dip as a result of those actions, no other nations followed our lead and production has returned to the previous levels already. Deforestatioin is a significant portion—some say 20 percent—of the global warming problem. But it is not deforestation of the North American continent that is of concern and how we convince some of the developing Nation's to change the direction of their societies is difficult for me to comprehend.

The third difficulty with respect to the global warming issue is that a large portion of the problem—in this case 40 percent—is due to the increase in carbon dioxide which results from the burning of fossil fuels. Fossil fuels are at the heart of our economy. It is hard to imagine the industrial revolution without coal, oil and natural gas providing the flame. Those on this Committee who have labored for years to reduce emissions of SO_2 from electric powerplants to solve the acid rain problem remain undaunted. But it is hard to even think about making the same case against CO_2 in the next cycle of the air pollution debate.

Given these three difficulties it is very tempting as a legislator to pass off this problem to somebody else. We could bounce the ball right back to the scientists giving them a big research budget and graduate fellowships and wait for years for the uncertainties to be reduced. We could pass it off to the Executive Branch and wait for them to produce miracles of cooperation in the international community. We could even try to pass it off to our children, leaving the response to the next generation where coping with problem rather than preventing it will be the order of the day.

But my hope, Mr. Chairman, is that we will not give into those temptations even in the face of the three large difficulties which I have outlined. Rather, I hope that we can break the problem down into smaller, more manageable pieces and get to work on what can be done right now. Senator Chafee has started that process for us by focusing on three of the chloroflourocarbon compounds . . . CFC −11, −12, and −113. These are significant agents both in the ozone depletion and global warming problems. As a nation, we ought to move as quickly as we can to find substitutes for these chemicals in all applications, so that they might be eliminated from commerce altogether.

As easy as it would be to continue sending money to the scientists or letters to the State Department or leaving the tough problems for our kids, I hope that we will do more than what is easy. We must to use the legislative authority given to this subcommittee by the Senate to take the steps that can be taken now to prevent further buildup of the trace gases in our atmosphere. I know that is the course our new chairman will want to take and I pledge my assistance in that legislative effort.

Senator MITCHELL. Thank you, Senator Durenberger.

We are pleased that Senator Baucus, the Chairman of the Subcommittee on Hazardous Wastes and Toxic Substances, who will cochair this hearing, has arrived.

Senator Baucus.

OPENING STATEMENT OF HON. MAX BAUCUS, U.S. SENATOR FROM THE STATE OF MONTANA

Senator BAUCUS. Thank you, Mr. Chairman.

Today's hearing is a joint hearing of the Hazardous Waste and Toxic Substances Subcommittee and the Environmental Pollution Subcommittee on the serious problems of ozone depletion and global warming. Global warming, which appears to be caused by the greenhouse effect, and stratospheric ozone depletion are international problems. The United States is the largest single source of global emissions of carbon dioxide, but we are only responsible for one-fourth to one-third of total worldwide emissions.

The apparent thinning of the protective ozone layer above the South Pole is troubling. NASA will be conducting major research this fall. So in as short a period as ten months we could find ourselves confronting a situation that demands drastic and immediate action.

Ozone depletion and global warming are interrelated environmental problems, and they pose the greates environmental challenge that our planet will face over the next century.

We are involved in an environmental experiment of worldwide dimensions. The problem is compounded since many of these chemicals will remain active in the stratosphere for decades. We will not be sure of the consequences of this experiment until the damage is done. Chlorofluorocarbons have been implicated as a contributor to the "greenhouse effect" causing global warming, and they are also responsible for loss of stratospheric ozone. A natural linkage exists between global warming in the troposphere and protection of the stratosphere.

Climate change and global warming are long-term problems, but the way we cope with them may be intimately related to one of our nation's most pressing short-term problems—economic competitiveness. Those countries that best anticipate future global needs, including environmental needs, are likely to achieve the greatest economic success in the future. Early anticipation of these environmental problems and thoughtful investment in their solutions can therefore be to our ultimate economic benefit. But first we must develop the efficient energy technologies, safe chemicals, and other alternatives on which the world's welfare will soon depend. If we must import these products and innovations from other countries, it can only hurt our economy.

The interrelated problems of ozone depletion and global warming may represent the ultimate challenge to the countries of the world that are too often preoccupied with self-interest. International cooperation to address the problem is critical. I am pleased that one of the witnesses here today, Dr. Wigley, is a visiting scientist from England. This type of international cooperation is critical.

Today's hearing builds on an effort started in this committee during the last Congress under the guidance of Senator Stafford, Senator Chafee and Senator Durenberger. Today's hearing is a joint hearing in order to demonstrate the high priority we give these issues. It demonstrates our commitment to confront the serious public policy issues posed by these problems.

Whether we are talking about the release of CFCs into the atmosphere or the burning of fossil fuels, discrete actions occurring throughout the world, even as minor as spraying an aerosol can, represent a threat to the entire planet. The potential effects are so large as to be almost unthinkable.

No single nation or isolated group of nations can solve this environmental problem. Despite our advanced technology and vast resources, the United States cannot solve this problem alone.

Last week, I had the opportunity to meet with Peter Usher, head of the atmospheric program of the United Nations Environment Program (UNEP). Peter Usher and Mostafa Tolba, Director of UNEP, are in large part responsible for bringing the world community to the bargaining table to discuss the control of CFCs.

These negotiations are critically important. Largely at the insistence of Lee Thomas, the United States has come forward with a commendable proposal for a cooperative effort to control CFCs.

During the first session to develop this protocol, a useful dialogue was undertaken, but self-interest prevented more from being accomplished.

It is inexcusable that after 28 nations came to agreement about the need to protect the stratosphere the representatives of the European Economic Community arrived in Geneva last December with no position and no power to negotiate. Japan and Russia must also share the blame for the negotiations getting off to such a poor start. Even the United States shares some blame because the final version of Lee Thomas' proposal was watered down and vague.

U.S. industry, both users and producers, has gone further to recognize the problem than many of the most developed nations of the world. American industry is to be commended for stepping forward.

These international negotiations must lead to a meaningful agreement. We must avoid the deadlock that developed between the United States and Europe in 1983. The nations of the world must be committed to protecting our environment—to protecting the planet. And the United States must take a leadership role within the international community.

The problem of global warning and ozone depletion have reached a stage that requires a broader and more institutionalized commitment to international dialogue. The focus for this effort should be the United Nations Environment Program (UNEP). It was created in part to serve this role. UNEP has already acted as a valuable catalyst for international scientific and governmental cooperation on the greenhouse effect, ozone depletion, and many other global environmental problems.

The United Nations Environment Program is preparing to undertake a vigorous international review of the research on global warning. This fact-finding effort will ensure that all nations of the world understand the seriousness of the problem. This effort is expected to play a pivotal role in developing an international commitment to address the problem. A vigorous timetable of taking action by 1992 has been set by UNEP. This effort is commendable.

The United States must make the necessary commitment of resources to lead this effort. But the administration has repeatedly sought to emasculate the UNEP budget by slashing the U.S. contribution. We must have a more substantial U.S. commitment to this important program. The United States must reestablish itself as a preeminent environmental leader in controlling pollution. President Carter in 1980 proposed freezing production of CFCs, but nothing happened. Not until Lee Thomas took over at EPA has there been any sign of willingness to come to grips with the stratospheric ozone depletion problem. A much larger commitment will be needed to address climate change. It is a complex problem involving both developed and undeveloped countries, involving both energy use and changes in the natural environment.

For example, an important but often overlooked contributor to the greenhouse problem is tropical deforestation. Experts tell us this problem may be responsible for as much as forty percent of current global emissions of carbon dioxide. The destruction of tens of millions of acres of this irreplaceable resource is occurring at an accelerating rate in many countries. This results in a large release of carbon dioxide in addition to the disasterous ecological consequences.

Ozone depletion, by contrast, is caused by a limited group of chemicals. These chemicals play an extremely important role in modern society, but we are talking about a small group of chemicals.

Ozone protection is a much more tangible problem than global warming. If we fail to find a satisfactory means to protect the stratosphere,we may find ourselves with no alternative but accepting the inevitable and adjusting to the consequences of that failure. I believe that profound climatic change will be even more difficult to accept than the comparatively minor steps required to prevent this catastrophe.

The ongoing discussions to develop an international agreement to control ozone-depleting chemicals, a topic of today's hearing, is a first step. But I am increasingly concerned that not enough is being done quickly enough to address these serious problems adquately. I have been working closely with Senator Chafee, as well as other member of the Committee, to develop legislation to take some concrete steps toward solutions. We must work together to ensure the success of this effort and find ways to address the larger issues surrounding global warming.

Senator MITCHELL. Thank you, Senator Baucus.

Senator Reid.

Senator REID. I have no opening statement.

Senator MITCHELL. I thank the Senator.

Senator Gore, would you care to make an opening statement?

Senator GORE. I have a statement that I will submit for the record and just take a minute to express my appreciation for your kindness in allowing me to participate in this hearing eventhough I'm not a Member of the committee.

Senator MITCHELL. Your statement will be included in the record along with the statement of Senator Lautenberg who is unable to be here today.

[The statements referred to follow:]

STATEMENT BY SENATOR FRANK R. LAUTENBERG JANUARY 28, 1987
HEARING--GREENHOUSE EFFECT, OZONE DEPLETION, AND CLIMATE CHANGE

MR. CHAIRMAN, I WOULD LIKE TO COMMEND YOU FOR CALLING THIS HEARING TODAY. WE ARE FOCUSING TODAY ON SOME COMPLEX AND SERIOUS ENVIRONMENTAL PROBLEMS FACING THIS NATION AND THE WORLD: THE GREENHOUSE EFFECT, OZONE DEPLETION, AND CLIMATE CHANGE.

THE EVIDENCE CONTINUES TO MOUNT THAT LINKS INCREASES IN GREENHOUSE GAS CONCENTRATION WITH GLOBAL WARMING. THERE IS GROWING EVIDENCE THAT OUR OZONE LAYER IS ERODING.

SCIENTISTS PREDICT THAT MEAN GLOBAL SURFACE TEMPERATURE WILL RISE BY 2.7 TO 8.1 DEGREES FARENHEIT BY THE MIDDLE OF THE NEXT CENTURY. THAT WOULD HAPPEN JUST IF FOSSIL FUEL USE CONTINUES TO PRODUCE CARBON DIOXIDE AT PRESENT RATES. THE ASSOCIATED RISES IN SEA LEVEL COULD BE AS MUCH AS TWO OR MORE FEET.

MR. CHAIRMAN, IT IS BECOMING CLEAR, THAT CONGRESS MUST BEGIN TO THINK NOW ABOUT AVOIDING THE MAJOR ENVIRONMENTAL THREATS OF CLIMATE CHANGE. THE PREDICTED RISE IN SEA LEVEL COULD HAVE DEVASTATING EFFECTS IN COASTAL STATES SUCH AS NEW JERSEY. THE VAST WETLANDS OF MY STATE COULD BE IMMERSED. THIS COULD CHOKE OFF THE EBB AND FLOW OF THE TIDES NECESSARY FOR THE BREEDING OF MARINE LIFE AND AQUATIC BIRDS.

INTRUSION OF SALTWATER UP THE DELAWARE RIVER, COULD JEOPARDIZE THE DRINKING SUPPLIES OF SOUTHERN NEW JERSEY. A ONE FOOT RISE IN SEA LEVEL, COULD ERODE AN ESTIMATED 125 FEET OF THE STATE'S SHORELINE. BEACHFRONT HOMES FROM SEA BRIGHT AND MONMOUTH BEACH TO STONE HARBOR AND CAPE MAY COULD BE LOST.

BUT THE PROBLEM GOES BEYOND THE COASTAL STATES. IT COULD AFFECT THE FARM BELT TOO. THERE IS SOME EVIDENCE SUGGESTING THAT THE PREDICTED CLIMATE CHANGES WILL MEAN LESS WATER FOR CROPS DURING THE SUMMER. AGRICULTURE IN DEVELOPING NATIONS COULD ALSO SUFFER.

THE DOCUMENTED EROSION OF OUR OZONE LAYER IS ALSO A MAJOR THREAT. OZONE DEPLETION CAUSES INCREASES IN THE ULTRAVIOLET RADIATION REACHING THE EARTH. THE RADIATION INCREASE COULD TRANSLATE INTO INCREASED SKIN CANCER.

THE PROBLEMS WE EXAMINE TODAY HAVE NATIONAL AND INTERNATIONAL CONSEQUENCES AND CAUSES. THEY REQUIRE GLOBAL COOPERATION AND COMMITMENT. THIS NATION MUST ACT, AS MUST NATIONS AROUND THE WORLD, TO RESPOND TO THE ACCUMULATION OF GREENHOUSE GASES AND THE DOCUMENTED DEPLETION OF THE OZONE LAYER.

THIS HEARING TODAY WILL HELP US AS WE PREPARE TO ADDRESS THESE PROBLEMS, AND I LOOK FORWARD TO THE TESTIMONY OF OUR WITNESSES.

Remarks of Albert Gore Jr.

before the Environment and Public Works Committee

January 28, 1987

Thank you, Mr. Chairman.

I am pleased to be here today with the Subcommittee on Environmental Protection and the Subcommittee on Hazardous Wastes and Toxic Substances in this hearing on The Greenhouse Effect, Climate Change, and Ozone Depletion. I want to commend you, Mr. Chairman, and the Subcommittee Members for calling this hearing on two of the most serious long-term evironmental problems facing the United States and the World, these are the greenhouse effect and depletion of the ozone layer.

Modern man has acquired the technology to catastrophically modify the fragile atmosphere of our planet. The greenhouse effect is caused by the buildup of carbon dioxide and other trace gases which trap radiation, causing the atmosphere to heat up. If today's worst case scenarios become tomorrow's facts, we will then have only a few decades in which to ameliorate the impact--which could range from drought in the midwest to floods on the coast. Some of the same gases implicated in the greenhouse problem are also culprits in ozone depletion.

For those unfamiliar with the greenhouse effect, it may sound more like a plot for a bad science fiction story than a serious environmental issue deserving public policy review of the highest order. But, given its serious and potentially drastic impacts, federal research and study efforts must place the greatest priorities on solving the mysteries surrounding the greenhouse effect. Otherwise, future generations may experience a science fiction horror story that comes true.

My interest in the greenhouse effect goes back several years and includes three congressional hearings which I chaired. During these hearings, scientists testified that manmade changes in the Earth's atmosphere would cause a greenhouse warming. Today we will hear further evidence that the greenhouse effect and ozone depletion are real and the time to act is now.

In October 1985, scientists from 29 countries met in Villach, Austria. These scientists concluded that "... greenhouse gases are likely to be the most important ~~casuse~~ causes of climate change over the next century." This conclusion was the basis for a recommendation that "governments... should take into account the results of this assessment in their policies on social and economic development, environmental programs, and control of emissions of radiatively active gases."

In the past few years, the scientific community has moved from uncertainty about the greenhouse effect to specific recommendations on how to address the issue. However, there are still disagreements as to the severity of the effect and the amount of time that we may have in order to ameliorate the impact.

In order to decrease the scientific uncertainties and to provide more information for policy makers, I have reintroduced Senate Concurrent Resolution 5 that would expand and focus scientific efforts on the greenhouse effect and its consequences for society. The legislation would call for the establishment of an international year of scientific study of the greenhouse effect, and would request that the President take steps to begin this worldwide cooperative investigation. This would be just the beginning, many of the studies would need to continue for years.

The legislation has four purposes. It would (1) coordinate and promote domestic and international research efforts on both the scientific and policy aspects of this problem; (2) identify strategies to reduce the increase of carbon dioxide and other greenhouse gases; (3) study ways to minimize the impact of the greenhouse effect; and (4) establish long-term research plans.

The concept of an international year of study has been used successfully in the past. In fact, the best and most complete collection of data of the atmospheric concentrations of carbon dioxide began in 1957 as a result of the International Geophysical Year. At that time a sampling station was established in Mona Loa, Hawaii. Today scientists are still collecting data from that station.

The greenhouse effect and ozone depletion seem out of scale when compared to the sorts of problems our political system is used to confronting. However we must ~~have got to~~ act now. When one jumps from the diagnosis of the problem to the prescription for solving the problem, some of the important solutions appear to be unimaginable. As policymakers, it is our responsibility to expand our imaginations to seek possible solutions to the two great threats to our global environment, the greenhouse effect and ozone depletion.

Thank you, Mr. Chairman.

Senator MITCHELL. We will proceed to our first panel of witnesses, Dr. Wallace S. Broecker, Dr. Tom Wigley, Dr. Ralph Cicerone, and Dr. V. Ramanathan.

Welcome, gentlemen, and thank you for your patience. We look forward to your testimony very much.

I believe that all or most of you have testified at congressional hearings before, so you are familiar with the practice. The written statements will be inserted in the record in full, and we ask you to provide oral testimony in approximately five minutes, following which you will be asked questions by the Members of the committee. We will begin in the order that you are listed.

Dr. Broecker, if you would proceed.

STATEMENT OF DR. WALLACE S. BROECKER, PROFESSOR OF GEOCHEMISTRY, LAMONT-DOHERTY GEOLOGICAL OBSERVATORY, COLUMBIA UNIVERSITY

Dr. BROECKER. Thank you, Senator.

It is a pleasure to hear you all make such strong statements about the danger of these problems. I agree with you.

I also have an axe to grind. I come here as sort of the prophet saying something about what is going to happen in the future. I am a scientist, and I will normally be accused of being here, I suppose, because a lot of things I am going to say have to do with preparing ourselves for what is coming.

There are going to be harsh changes, regardless of what legislation you make, and we are going to have to learn to cope with them. The systems that we are impacting, I feel, are extremely complicated, that we greatly underestimate the complexity that they have and, therefore, the manner in which these impacts are going to come upon us.

I think that one must pass along more money to the scientists, and I think that one must pass it through different pockets than it is going through today, because the pockets that it is going into, the emission oriented agencies, have the feeling that they can solve this problem in a few years, with quick fixes and literature searches.

I have been in this science for a long time, and I know that that is not true. I see where the important new evidence is coming from, and that important new evidence is coming from basic research that we are doing. It is just like cancer research, you are not going to legislate cancer out of existence. You are going to have to go back and study the basic support research, study the cell, and understand the actual processes that are going on.

Unless we double, and redouble, and redouble again our efforts to understand the ocean files, soil moisture, and various things, we are not going to be as prepared as adequately as we could be to deal with these things when they come, and they will come because there is no way in hell that we can stop putting these greenhouse gases into the atmosphere. Some will go in, and climate will change.

My own view of things has suggested a new angle on this whole matter, and that is, when we look at the climatic record over the last million years, which is dominated by these large glacial cycles,

we now realize that these cycles were driven and are being driven by rhythmic changes in the orbit of the earth about the sun. It is around us, and the orbit is changing. The earth itself is recessing.

These are cycles of 20,000 to 100,000 years. Yet, when we look at them, and we are convinced, we have very good evidence now that there is a driving force. Despite that these are very gradual changes, our earth has not responded in a gradual way. In my testimony, I show that, particularly in the North Atlantic Basin, where we have very good evidence, this system responded in very sharp jumps, and we think that we now understand something about these jumps.

These jumps involve reorganization of the whole ocean atmosphere system. An analogy might be that if you lived in India, the monsoons would come just in one day. They are being driven by the seasonal cycle of what happens as the air circulation in the Indian Ocean reverses itself, and when it reverses, it suddenly starts to rain.

I think that the evidence we have, the only true experiments that have ever been done are experiments that have been done by the planet all by itself, is strongly telling us that the climate changes that we have seen have largely involved the jumps in the system. It is like your radio, when you have it on automatic frequency control, it jumps from one station to another. That is the kind of thing that I am talking about.

This is a very complicated business. It is the worst kind of response that you could get in the system. The danger to the future is if, instead of having the climate change gradually along with a gradual build-up of these gases, we come to certain points where the system decides to reorganize, and all of a sudden, over a few decades, we have major changes in regional climate.

We won't ever be able to predict exactly when these will come, and maybe not even what they are, but what we can do is get ready to say, well, if they do come, at least we have been thinking about them and we will be monitoring things that may allow us to say how far the change is going to go, whether it is going to reverse, and things like that, maybe even what we would do, if we were faced in our agricultural situation with more dramatic changes than ones that occur on a 100-year time scale.

My message to you is that we must do far more research if we are going to understand these systems. I have seen it, and I know a lot about environmental science, we have wasted a lot of money over the last 20 years that could have been saved if we had started out right in Rachel Carson's time and said, we are going to build a base of knowledge that every decade will allow us to be in a little bit better position to answer these questions.

We have done some of that, but I would say, in general, we have botched, and we botched it—partly it is your fault—because you want answers to questions on a very short time scale. You push DOE. You push EPA. I think that the only solution is to get this research out of the political environment, isolate it in some entity in the U.S. where it goes on regardless of the immediate political pressures, and those things that are handled otherwise.

When I testify like this, I am being very critical in particular of DOE, which runs the nation's CO_2 program, and is the greatest po-

tential supporter of my research. So in telling you this, I endanger my own research support. They have been reasonably good to me, but it certainly doesn't make them too happy when I say I think that they are botching it.

I don't think that they are doing the proper things with their money. I don't think that they are looking ahead at long-range problems, and somehow this has to be turned around, and our country has to pay the proper respect to basic research that we need, just as we do, let's say, in the area of cancer research, which I think is a very complicated problem.

Thank you.

Senator MITCHELL. Thank you very much, Dr. Broecker.

Dr. Wigley.

STATEMENT OF DR. TOM M.L. WIGLEY, DIRECTOR, THE CLIMATIC RESEARCH UNIT, UNIVERSITY OF EAST ANGLIA, NORWICH, UNITED KINGDOM

Dr. WIGLEY. Thank you, Mr. Chairman.

It is certainly a great honor to be invited to this meeting. I am currently a Visiting Scientist at the National Center for Atmospheric Research in Boulder, Colorado.

I would like to show a couple of transparencies to set things up.

This background shows changes, very large area changes in temperature of the Earth's surface. There are three figures there, and they show the mean temperature for the Southern Hemisphere, the Northern Hemisphere, and the globe.

These data have only become available quite recently, and the reason for that is that, in order to get a large area picture, a global picture, one needs to have data for the oceans—70 percent of the Earth's surface is covered by oceans—and it is only very recently that reliable data have become available for the ocean areas.

The diagrams actually represent true land and ocean averages, and they confirm things that we knew before, or at least we thought we knew. That is that over the last 100 years there has been a long time scale warming, which amounts to about half a degree centigrade (which is almost one degree Fahrenheit) since the late 19th Century. This warming is common to both the land and ocean areas, and it is common to both hemispheres.

The leading question then is just what is the cause of this warming. We don't know the answer to that for sure, but there are a number of factors that we know can affect global mean temperatures. Greenhouse gas changes is one of the factors. Another is changes in solar output. Another possibility is changes in volcanic activity, which affects the amount of sunlight that reaches the Earth's surface. Another factor is that the climate of the planet itself is internally very complicated.

Let me pursue in a little more detail the potential effects of greenhouse gas changes, and I will show another transparency.

Senator GORE. Mr. Chairman, while he is getting the transparency set up, is it my understanding that before this study was made, we relied almost exclusively on temperature measurements taken on land, which had a very high noise level, which obscured some of the longer term trend. Is this the first time that we have had any

ocean ambient temperatures that filtered out some measure of the noise level in the earlier studies?

Dr. WIGLEY. That is quite correct. Until quite recently we relied on data from the land masses of the Northern Hemisphere only, and that area constitutes quite a small fraction of the Earth's surface, as I am sure you are aware.

Senator GORE. I am trying to make a brief point, Mr. Chairman, that what this testimony represents is another step for eliminating residual uncertainties. Before this groundbreaking study was made, there was a lot of confusion about whether or not the increase that they saw was real, and this has confirmed it.

Dr. WIGLEY. That is quite correct. This certainly reduced some of our uncertainty in knowing what the changes in the past have been.

I compared the theoretical limits of warming due to greenhouse gas changes—that is carbon dioxide and all of the other trace gases combined—I compared that theory to the observed warming. The theory is indicated by the two smooth curves, which are an indication of the range of theoretical uncertainty. Superimposed on that are the observations of global mean temperatures that I showed you previously.

You can see from this diagram that the overall trend, on the 100-year time scale, is quite consistent with our understanding. You can also see that there are other perturbations at the global scale that are clearly not due to greenhouse gases.

In particular, between 1940 and 1970, the curve flattens off a little bit. We don't know yet for sure what the cause of that flattening off is. Other fluctuations are manifestations of the natural variability of the climate system. But the very long time scale change is quite clearly compatible with the greenhouse gas hypothesis. This does not mean that we have unequivocally proved that this is due to greenhouse gases, but it is probably the best explanation that is available at the present time.

I have also projected ahead the warming, based on the same theoretical models, up to the year 2050. If you look at the diagram, you can see that from 1985 to 2050, a 65-year period, the additional warming ranges, in terms of uncertainty, between a warming of 1.4 degrees centigrade to a little over three degrees centigrade.

In fact, those numbers are a little smaller than the numbers that the Senators quoted earlier, and the reason for that reduction is that the numbers they were quoting were the equilibrium warmings, the potential warmings. This warming, as shown here, allows for the thermal inertia of the oceans, which causes a lag in the system, or a damping of the manifested warming due to greenhouse gases.

This is both good and bad. It is bad because, in slowing down the warming, it makes it hard for us to detect the warming. Another reason why this is a bad thing is that it means that, at any one time, the warming we see is maybe only 50 percent of the potential warming.

In other words, if we could cut off the production of greenhouse gases now, and keep the concentration in the atmosphere at the present state, the Earth would continue to warm, and it would continue to warm by a considerable amount over the coming decades.

So we are committed to this future warming no matter what our policies are going to be with regard to regulation.

To close, I would like to just put this into a very long time scale, and that is, what is the significance of the observed warming, or the present warming, compared to the changes that occurred in the past.

What we know almost certainly is that the temperature levels that we are feeling today (you can see the last points on that curve are considerably warmer than at any time in the immediate past. In fact, we are pretty sure that the levels of temperature today are warmer than has been experienced for many thousands of years, probably six to eight thousand years.

If you look at the warming expected by the year 2050, that level of temperature is warmer than anything that the Earth has experienced for at least two million years. We are talking about something that is not only unprecedented in human experience, but unprecedented on a much longer time scale.

Thank you very much.

Senator MITCHELL. Thank you very much, Dr. Wigley.

Dr. Cicerone.

STATEMENT OF DR. RALPH J. CICERONE, DIRECTOR, ATMOSPHERIC CHEMISTRY DIVISION, NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Dr. CICERONE. Thank you, Senator Mitchell, and Senators. I will try to summarize the key parts of my written testimony very quickly. I will try to cover the topics of interest that I think you wanted me to address.

Scientists now know enough about the properties of chemicals that can be effective greenhouse gases that we can list the potential key contributors to the effect and we can also dismiss many other chemicals that do not possess the right properties, so that we can avoid just creating a shopping list.

I summarize data on greenhouse gases that are actually piling up in the atmosphere, and then chart some of the relationships with ozone depletion, and with acid deposition.

Professor Broecker, in his written testimony, summarized a great deal of the information on carbon dioxide, so I will proceed to mention a few of the others.

Methane concentrations have risen about 100 percent in the last 150 years or so, and in the last 35 years we have seen a 30 to 40 percent increase. Human activities are quite capable of having caused these recent methane increases and of continuing such a trend in the future. We increase the source of atmospheric methane by expanding rice agriculture and herds of ruminant animals.

We may also be suppressing the atmosphere's natural ability to assimilate methane by dumping other pollutants like carbon monoxide into the air, through connections that have to do with atmospheric chemistry.

The two principal fluorocarbons that are implicated in the greenhouse effect and stratospheric ozone depletion are fluorocarbon-12 and 11. These are totally synthetic chemicals so neither of them was present in the pre-industrial atmosphere. As you know, the

concentrations in the present atmosphere are growing at a rate of about 5 percent per year.

Future increases in atmospheric fluorocarbon concentrations are fully expected. Even if emissions do not increase further, concentrations will increase for the next several decades because of the long time needed for atmospheric destruction processes to equilibrate with a steady input.

Emissions to the atmosphere will increase if the industrial production and usage increase, and there are economic projections that show a continued or a growing demand for these chemicals, or possible substitutes for them. Without international regulations, the emissions of these chemicals could increase by 2 to 3 percent annually, as has been estimated.

In the case of nitrous oxide, we are unsure as to why it is increasing, but measurements from all over the world have established that it is. The 1986 concentration was about 300 parts per billion. Pre-industrial nitrous oxide concentrations were lower, about 280 parts per billion. These concentrations are growing at about two-tenths of a percent per year. This may sound small, but it takes a lot of nitrous oxide to amount to that increase.

Two possible sources seem likely. One is the inadvertent loss of artificial nitrogen fertilizer from fertilized fields and from subsequent nitrogen cycling. The other is the combustion of nitrogen-rich fuels. World demand for nitrogen fertilizers keeps growing.

In 1950, only about three million tons of nitrogen fertilizers were produced worldwide. In recent years, the annual total was over 50 million tons. Similarly, as you know, fuel combustion increases at 2 to 4 percent per year, although the mix of fuels varies and the rates track the general economy.

Ozone in the lower atmosphere is potentially a greenhouse gas. Data will show that it is increasing in the Northern Hemisphere, where there ~~is more~~ human influence, perhaps by 1 percent per year, but the situation here is not as clear as for the other greenhouse gases. There are new indications from European scientists that background ozone concentrations at the turn of this century were well below those at present, perhaps only one-third as large.

Now in relation to stratospheric ozone depletion, we have some important connections that several of the Senators have already mentioned. The key greenhouse gases, the two fluorocarbons, nitrous oxide and methane, also affect stratospheric ozone strongly. These gases have atmospheric survival times that are long enough to permit them to make the upward journey into the stratospheric ozone layer.

In the harsh ultraviolet light there, the fluorocarbons are decomposed, yielding chlorine atoms that destroy ozone, similarly for nitrous oxide. Methane acts to slow the attack on ozone, but it also decomposes to yield molecular fragments that are involved in ozone destruction.

Interestingly, present models say that the chlorine attack on ozone will be slowed somewhat if in the future nitrous oxide and methane continue to increase along with the fluorocarbons. But the slower decrease of total ozone will result in a redistribution of ozone toward the lower altitudes, and I believe that Dr. Ramanathan, in his testi-

mony, mentions how this can increase the warmness of the earth and the greenhouse effect.

Carbon dioxide is not involved chemically, but once in the upper atmosphere, it acts to cool the air by radiating energy to space. This cooling should also act to slow the chlorine attack on ozone a little bit.

As to the antarctic ozone hole, more complicated phenomena may be occurring there, where the ozone concentrations have decreased greatly in the past 15 years or so. The same ozone-destroying chemicals just mentioned are probably at play, but through more complex pathways, I believe.

In any case, it is very important to learn what the mechanism behind the formation of this Antarctic ozone hole is, because we want to be able to predict in the future whether the hole will worsen and spread and go north, or whether it will stay the same, or whether it will disappear. We must know the mechanism. Of all the gases relevant today, in the greenhouse effect and the stratospheric ozone depletion, the fluorocarbons do stand out.

I should mention that recently two U.S. industrial groups proposed that international agreements be sought to limit the future growth of emissions to the atmosphere of fluorocarbons. In this way, steps could be taken to contain future greenhouse and ozone depletion effects.

The relationships between regional acid deposition and the global greenhouse effect are not as direct as for the greenhouse effect and stratospheric ozone depletion. The strong acids in precipitation, sulfuric, nitric and formic, are formed from emissions of sulfur dioxide, nitrogen oxides and hydrocarbon pollutants.

These pollutants are generally short-lived compared to the greenhouse gases. None of these pollutants are effective greenhouse gases although nitrous oxide is often formed in the same processes that produce the more common nitrogen oxides. Of the key greenhouse gases, only tropospheric ozone is involved in the formation of atmospheric acids.

A strong and broad link between the two phenomena is made, however, through the chemistry of the atmosphere. Hydrocarbon and nitrogen oxide pollutants react to produce ozone. All of these plus carbon monoxide control the rates at which acids are formed by oxidation and they also set the levels of other oxidants, like OH radicals, that bear the atmosphere's ability to oxidize and decompose methane. It is possible that the buildup of methane stems partly from the effects of other pollutants on the whole system. The oxidizing power of the atmosphere is the link and at this time we do not understand very well at all how the chemistry of the troposhere where much of this oxidizing power appears.

Senator MITCHELL. Thank you very much, Dr. Cicerone.

Dr. Ramanathan.

STATEMENT OF DR. V. RAMANATHAN, DEPARTMENT OF GEOPHYSICAL SCIENCES, UNIVERSITY OF CHICAGO

Dr. RAMANATHAN. Scientific concern for the climatic effects of an increase in the atmospheric concentration of CO_2 dates back to the late 19th Century. It is only within the last decade that we have

become aware that human activities are causing an increase in the atmospheric concentrations of not only CO_2, but several other greenhouse gases as well. As a result of the intense observational and modeling studies undertaken since the mid-1970s, the problem concerning the greenhouse effects of human activities has broadened in scope from the CO_2 climate problem to the trace gases climate problem.

As perceived currently, the important greenhouse gases with respect to human activities are CO_2, methane, chlorofluorocarbons, in particular CFC-11 and CFC-12, nitrous oxide, and ozone. These gases trap infrared radiation emitted by the surface of the earth, which would have otherwise escaped to space. It is this trapping of the infrared radiation which is referred to as the greenhouse effect, particularly since the gases let the solar radiation penetrate to the surface.

An increase in the concentration of the greenhouse gases leads to increased trapping of infrared radiation and thus causes an excess of radiative energy available to drive the climate system. This excess energy can be intuitively expected to alter global and regional climate patterns since radiative energy is the fundamental energy source for climate and the circulation of the atmosphere and the oceans. Certain trace gases are more effective than others in enhancing the greenhouse effect. For example, adding one molecule of CFC-11 and CFC-12 to the atmosphere can have the same radiative effect as adding 10,000 molecules of CO_2.

From the pre-industrial era to the 1950s, the greenhouse effect of CO_2 was the major source of anthropogenic impact on climate; this picture has changed drastically since the early 1960s. Non-CO_2 greenhouse gases in the atmosphere are now adding to the greenhouse effect by an amount comparable to the effect of CO_2 increase.

The rate of decadal increase of the total radiative heating of the planet is now about five times greater than the mean rate for the period 1850-1960. The year 1850 is arbitrarily taken to be the year marking the end of the pre-industrial era. From the 1850s to the present, the trace gas greenhouse effect is estimated to have caused an increase in the radiative heating of the planet by an amount that is equivalent to an increase in the sun's brightness by about 0.75 percent. (See table 1.)

Table 1. Summary of Greenhouse Estimates

Source: Ramanathan, Callis, Cess, Hansen, Isaksen, Kuhn, Lacis, Luther, Mahlman, Reck, and Schlesinger, 1986

Global Average of Absorbed Solar Energy = 240 W. m^{-2}

Period and Item	Radiative Forcing ($W. m^{-2}$)	Equilibrium Temperature Change
A. 1850-1980 (Cumulative Effect)		
CO_2	1.3	0.5 - 1.5[3]
All trace gases[1]	1.8	0.7 - 2
B. Post 1980 (Per Decade)[2]		
CO_2	0.24	.1 - .3
All trace gases	0.47	.2 - .5

[1]Includes CO_2, CH_4, CFC's, O_3, N_2O and several others

[2]Based on observed trends for 1975 to 1985

[3]The upper value reflects the climate sensitivity of 3-D climate models; the lower value reflects the sensitivity of a model with very little climate feedbacks

Climate models are needed to translate the radiative forcing in terms of a climate change. The most sophisticated climate model that is available for this purpose is the three-dimensional general circulation models (GCM). GCM studies conducted at various national research centers suggest a global average surface warming in the range of 3.5 to 4.5 degrees centigrade for a doubling of CO_2. Simpler conceptual models that ignore several of the feedbacks modeled in the GCMs indicate a warming in the neighborhood of 1.5 degrees centigrade. Hence, it has become customary to use a range of 1.5 to 4.5 degrees centigrade as reflecting the uncertainty in our understanding of the doubled CO_2. This range in model sensitivity has been used to translate the trace gas radiative forcing to a global average temperature change.

According to such model estimates, the observed and postulated increases in the trace gases, between the year 1850 and 1980, have committed the planet to an equilibrium warming of about 0.7 to 2 degrees centigrade. The 2 degrees centigrade is based on the sensitivity of three dimensional climate models. Because of the inertia

of the world oceans, only a fraction, about a third to a half, of the equilibrium warming is expected to be manifested in the observed records by now.

Time dependent one-dimensional ocean model calculations indicate that the trace gas warming will become large enough to rise above the background climate noise before the end of the century. At the current observed rate of increase in the trace gases, the greenhouse equilibrium warming of the globe increases by 0.2 to 0.5 degrees centigrade for each decade.

The surface warming will be accompanied by a significant cooling of the mid to upper stratosphere, i.e., altitude above 30 km. The magnitude of the stratospheric cooling is larger than the surface warming by factors ranging from 2 to 4.

Model studies that have attempted to project into the future suggest that the cumulative effects of trace gases from the pre-industrial era to the year 2030, 50 years into the future, is in the range of 1.5 to 6.1 degrees centigrade. The upper range assumes unabated continuation of current growth rates of the pollutants and also adopts the sensitivity of three-dimensional climate models. The lower range assumes severely reduced growth rates and also assumes a climate sensitivity that is smaller by a factor of three than that of the three-dimensional models.

In order to find past analogues to a warmer earth, one has to go back to the hypsi-termal period of 8,000 years ago for an earth warmer than the present by about 1 degree centigrade and to the early Tertiary to Cretaceous period of about 40 to 70 million years ago for an earth warmer than the present by more than 5 degrees centigrade.

In terms of the change, the climate system oscillates between glacial and interglacial events. We are currently in an interglacial period and the peak of the interglacial occurred about 8000 years ago. The glacial maximum occurred between 14,000 to 22,000 years ago when the global temperatures were about 5 degrees centigrade colder than today.

In effect, temperature changes in the range of several degrees celsius have occurred in the past but over time scales of thousands of years. Hence, concern with respect to human impact on climate is not only on the sign and magnitude of the change but is also on the time rate of change of that magnitude.

The enormous uncertainty in the climate model estimates of greenhouse warming is largely due to the uncertain role of clouds. Clouds have significant effect on the radiative heating of the planet and a few percent change in the cloud amount can offset or amplify significantly the greenhouse forcing due to the observed trace gas changes during the last century. Currently, neither the sign nor the magnitude of this cloud feedback is known.

Model studies pertaining to the CO_2 climate problem suggest that the global greenhouse warming will be associated with substantial changes in other climate parameters and in the regional climate. Some examples are given below.

Precipitation: A warmer ocean will evaporate more moisture which will ultimately fall to the ground as precipitation. Hence, a warmer globe will also be more humid and wetter.

Melting of sea-ice: The warmer air in the trace gas rich atmosphere will melt the sea-ice in the polar oceans. This will lead to increased absorption of solar radiation. Since the ocean underlying the sea-ice is much darker than the ice, melting of sea-ice will lead to increased solar absorption. The increased solar heating will feedback both on the atmospheric and oceanic circulation.

Polar amplification of the warming: The increased solar absorption resulting from melting of sea-ice and snow amplifies the greenhouse warming in the polar regions. The magnitude of the amplification varies typically by factors from two to four.

Mid-latitude and mid-continent drying: The combination of early melt of snow, enhanced evaporation of moisture from the hotter soil and circulation changes is computed to lead to a drying of the continents in mid-latitudes.

Other postulated effects include increasing sea-level, due to melting of glaciers and thermal expansion of sea- water; increased frequency of tropical storms since their frequency of occurrence is critically tied to tropical sea-surface temperatures and increased monsoonal rainfall in tropics. It should be stated that there is a high degree of uncertainty in all of the computed and postulated regional changes. Nevertheless, the qualitative nature of the predicted changes are based on sound physical principles.

In summary, the observed and projected increases of trace gases are estimated to cause unprecedented global and regional climate changes. The model estimates are subject to enormous uncertainties. The uncertainties arise due to the difficulty in projecting the future concentrations of gases and due to the threefold uncertainty in the climate model sensitivity.

The fundamental issue that we will face during the next decade is to develop a strategy for identifying the trace gas effects in the observed climate records. In order to accomplish this goal, we need long term global observations of the planetary albedo, an important climate forcing term that can enhance or offset the trace gas effects, and the hydrological cycle variables such as precipitation, water vapor, cloud effects on radiation budget in addition to maintaining the current global observing systems. In the absence of such global observing systems, we have to rely on circumstantial evidence for identifying the trace gas effects on climate.

Senator MITCHELL. Thank you very much, Dr. Ramanathan.

We appreciate very much the testimony. We will now proceed to questions by Members of the committee in order in which the Members arrived. We will follow the five-minute rule for the first round of questions.

Before we do that, I would like to recognize the former chairman of the full committee, and now the Ranking Member, responsible for much of the progress made in protecting our environment in this country and the world for at least a decade.

Senator STAFFORD. Thank you very much, Mr. Chairman. I have no formal opening statement, I might have a brief paragraph when the next panel comes up.

At this point, I think that these are excellent hearings, and I congratulate you on holding them. I am very much interested in them.

Senator MITCHELL. Thank you, Mr. Chairman.

I would like to ask Dr. Wigley the first question.

Does the analysis of your data lead you to personally believe that the observed increase in average global temperature is a greenhouse signal? Are we already experiencing the greenhouse effect?

Dr. WIGLEY. Senator, this is an easy question to answer because you said personally, and, personally, the answer is yes. I do believe that the warming is largely due to the greenhouse effect.

Senator MITCHELL. I would like to ask each of the panelists to respond in order to the following question:

We understand that you are scientists, and not policy-makers, and we do not expect you to give us a detailed assessment of policy alternatives, but I would like to ask if policy options are available which will slow the build up of greenhouse gases, and do you personally favor such action based on the information you have now?

We will begin with Dr. Broecker.

Dr. BROECKER. Yes.

Senator MITCHELL. Dr. Wigley?

Dr. WIGLEY. Yes.

Senator MITCHELL. Dr. Cicerone?

Dr. CICERONE. Yes.

Senator MITCHELL. Dr. Ramanathan.

Dr. RAMANATHAN. Yes.

Senator MITCHELL. Thank you very much.

Dr. Cicerone, could I ask you to elaborate briefly on your comment on page 8 of your statement regarding the relationship of the greenhouse effect and acid deposition. Is there a direct link? Is the connection between those two problems due to chemical reactions in the atmosphere. If you could provide us with a little more detail, please, on that issue?

Dr. CICERONE. The link is a little less direct than simply the emissions leading to one effect versus the emissions leading to another effect. The link that we see has to do with the way the atmosphere processes pollutants. For example, the build up of photochemical oxidants from pollutants also leads to faster production of acids in the atmosphere. Depending on how the oxidants in the atmosphere are affected, if the OH concentrations, which is one of the oxidants, in remote regions of the atmosphere are suppressed, then this would lead to a faster buildup of methane.

These are not terribly direct connections. As we understand the system better, we may say that they are more direct, but right now they don't appear to be as direct as the link between stratospheric ozone depletion and greenhouse gases.

Senator MITCHELL. Dr. Broecker, I would like to ask you what do you think is the likelihood of what some have referred to as greenhouse surprises, that is relatively sudden climate changes.

Could you give us some idea of the probability that Europe will experience climate changes suddenly and dramatically that will leave us little option but to adapt?

Dr. BROECKER. I cannot state the probability. All I can state is that as we get a better record indication of how the earth responded to the only experiments, such as the ones we think are driven by these hurdle changes, we see that there the response appears for many reasons to be very sharp and repeated. We start, as I said, to see the fact that the system can reorganize.

We are starting, I think, to think more and more about the mechanisms of reorganization, but this is a relatively new field. Often in science there are papers that talk about this that are perhaps obscure, but suddenly when we see some visible evidence that these things are actually happening, then people turn things around and apply them to the questions, and they start to think about it. As we start to think about it, we can see lots of reasons why this might happen, but we are not prepared at all to state what the probability is. I can only say that these will not happen in the computer model.

They are prevented from happening in the computer model because the computer models do not have the components in a form where they can happen. They don't have them in that form because, in particular, the ocean, we don't know enough about it in order to make a full dynamic model, including both the oceans and the atmosphere. People are struggling to do that, and I would maintain that this is a job that will require decades before it can be done effectively, but this is something that we must do. Until we can even round the ocean, and stay with the current atmosphere, it is impossible to explore in those models what might be required in order to flip the ocean atmosphere system into some alternate mode.

So it is a new thing, and I don't bring it forward as a scare tactic, I am just bringing it forward as a means of trying to emphasize that because we make simple computer models of this system, we are forced to do that, we often start to believe that the system is really as simple as our computer models.

I am convinced, no doubt about it, that it is much more complicated than that, and it has all sorts of linkages that we haven't even dreamed, and that they are likely to be operative. So we have to push forward and learn about the things that we are monkeying with.

Senator MITCHELL. Thank you, Doctor.

I would like to turn now to Senator Baucus, who is the cochair.

Senator BAUCUS. I thank the chairman, but I think that we should follow the rule.

Senator MITCHELL. You are next.

Senator BAUCUS. Thank you, Mr. Chairman.

Gentlemen, it seems to me that perhaps we should focus our attention on all of the causes of the greenhouse effect, that is, the CO_2, the methane, and CFCs, but primarily on CFCs at this time. I say that because the CO_2, as I understand, are about 50 percent of the greenhouse effect, and CFCs are about 15 percent, in that range somewhere, and methane is about 20 percent, and the nitrous oxide is about 10 percent, roughly.

We know that a lot of those gases come from natural causes, whereas the CFC, even though they only account for about 15 percent, is a man made cause. Also, as I understand it, CFC is an emission, which is not only an intensive cause of the greenhouse effect in the lower atmosphere, but it also breaks down ozone in the upper atmosphere. So it causes two problems. It is two for one.

My question is, is it fair to assume that we know enough about the chemistry and physics of CFCs to focus on that one gas now? I am not saying that we shouldn't do research on the others, but

focus now on CFCs, which is probably the greatest source that we can get a handle on because it is manmade.

Would each of you please respond.

Dr. CICERONE. Yes, Senator Baucus, I generally agree with you. I think, though, that the willingness to focus would depend on the amount of stake one has in the matter. One might require a lot more proof if one were directly involved financially. I am sure that this is the way many people would feel.

It is true that the chlorofluorocarbons are the simplest to understand. Personally, I believe that actions against the less essential usages are justified and have been justified for some time, including more stringent actions to be undertaken now.

But I think that we should not let out of sight some of the other easy steps that we could take in other cases. For example, with carbon dioxide, we haven't taken any, or not nearly the steps that we could on energy conservation in this country.

Senator BAUCUS. Would others like to comment?

Dr. RAMANATHAN. The CFCs are more complicated than they are made out to be in the papers. What we talked about so far concerns only the direct greenhouse effects. In addiiton, the change in the stratospheric ozone, due to CFC's, can also alter the climate because ozone is an important greenhouse gas and also modulates the sun's energy reaching the surface. Given such complex atmospheric effects of CFC's, I certainly agree with you.

Senator BAUCUS. Is it true that carbon dioxide and methane can increase ozone in the upper atmosphere?

Dr. CICERONE. In our present models that is correct, but the compensating effect is such that there should also be a redistribution of ozone toward lower altitudes, which would intensify the greenhouse effect of the ozone. So you win on the total column of ozone above your head, at least in our present understanding, but you lose on the greenhouse effect by allowing carbon dioxide and methane to increase the ozone at lower altitudes in the stratosphere.

Senator BAUCUS. What you are saying is that even though CO_2 and methane do tend to increase ozone in the atmosphere, still there is an adverse greenhouse effect.

Dr. CICERONE. Yes.

Senator BAUCUS. What about substitutes for CFCs, do you know if they cause problems?

Dr. CICERONE. We know their properties very well. I think the difficulty the industry has had is coming up with substitutes that satisfy all the right properties. Chemically, if you tell us about the compound you are going to use as a substitute, we can tell you pretty well what its relative impact will be on the ozone layer and the greenhouse effect. There are some attractive potential substitutes that would be less inert, for example, that would decompose more rapidly, with less long-lasting effects.

Senator MITCHELL. Thank you, Senator Baucus.

Senator Gore.

Senator GORE. Mr. Chairman, I appreciate the great courtesy you have shown me, not being a Member of the committee. Thank you for that.

Dr. Broecker, just to follow up on the chairman's question about the possibility of a sudden increase. What we are talking about here is a shift in equilibrium. Is that correct.

Dr. BROECKER. Yes.

Senator GORE. One way that I have heard it explained is that a world weather system is in a state of equilibrium at this point, but if you change some of the underlying factors and it is not out of equilibrium, and then in a relatively short period of time it searches for a new equilibrium. Is that fair representation?

Dr. BROECKER. That is a fair representation. In other words, there are a number of ways that the earth system can function, under certain climatic forces, and they do not occur overnight.

Senator GORE. I wanted to follow up also on the question of fluorocarbons with Dr. Ramanathan. Are you familiar with the EPA study due to come out in the spring on CFC levels. I am told that it concludes that if there was an 85 percent reduction in emissions of CFCs tomorrow, then the level of CFCs in the atmosphere would remain constant for the rest of time.

If, from this point on, we put no more than 15 percent of the current levels out into the atmosphere, it would not reduce the total amount of CFCs in the atmosphere by one iota.

Dr. RAMANATHAN. I am not that familiar with that particular study, but I would anticipate that because of the long lifetime of the CFCs lasting from 75 to 150 years.

Senator GORE. To be clear about it, if we reduce the emissions by 85 percent, there would be an increase in the level of CFCs in the atmosphere, and then they would come back down to the present level, and remain stable.

Dr. CICERONE. I have some of those numbers in my head. I haven't seen or heard about any study, but right now, each year of production increases the amount in the atmosphere by about 5 percent. So one year's production is one-twentieth. If we would now put 15 percent of one year's production into the atmosphere, we would then add about 3 or 4 percent of what is in the atmosphere now each year.

If there were no losses, or removal processes, a 15 percent annual release would still give us a 3 or 4 percent increase next year. However, there is atmospheric removal due to the ultraviolet radiation in the ozone layer that works at about 1 percent per year. These chemicals last about 100 years. So, if you can focus on a graph in your mind, there will be an initial increase, a continued increase in 1988 and 1989, leveling off in the next several decades, and then you start to see a decrease in the atmospheric destruction processes.

Senator GORE. That is if you are leveling off.

Dr. CICERONE. In the end, you end up with about 15 percent as much in the atmosphere as if we continued at today's rate.

Senator GORE. Dr. Ramanathan, you also testified that as much as a 2 percent increase for any given model. Is that correct?

Dr. RAMANATHAN. Did you mean 2 percent?

Senator GORE. Two degrees, and that if we continue our present practices, we will increase the amount of temperature growth by a half a degree per decade. Is that correct?

Dr. RAMANATHAN. Yes.

Senator GORE. Dr. Cicerone, when do you expect that we will be able to see the results of the Antarctic Expedition, which gathered such a large quantity of data on the ozone problem?

Dr. CICERONE. I cannot violate the confidence of my colleagues who told me what they are seeing. It is very difficult, for example, to get the spectroscopic data interpreted. They are having to use such high powered computers to reduce their data that it may take several months before they know what they saw. The primary indications are that they can rule out certain classes of theories and place emphasis on others.

I hate to be one of these scientists that tell you that we need three or four more years on a particular problem. The results that we are seeing are complicated enough to indicate that chemicals are involved, but they can't point a smoking gun at any of their suggestions yet.

Senator GORE. A final question for a brief response from all four. Do you support the idea for an International Year of the Greenhouse Effect?

Dr. BROECKER. I would support anything that would upgrade it. I think that we have to do more or we are going to be sorry if we don't understand more about our system.

Dr. RAMANATHAN. I would certainly support that because I think we need more education of the public and future scientists in this area.

Dr. CICERONE. Yes, unfortunately, I agree with Dr. Broecker that sustained work is essential, but, look at the benefits of what happened with things like the International Geophysical Year in 1957; I believe that this is how the British Antarctic Survey got started. Yes, that kind of consciousness is very important.

Dr. WIGLEY. I certainly support the concept, and I recommend that we institute it as quickly as possible, really.

Senator MITCHELL. Thank you, Senator Gore.

Senator Burdick.

Senator BURDICK. Thank you, Mr. Chairman.

I thank the panel for enlightening us. The question that runs through my mind is what should we do now as a global effort? Do we need legislation?

Dr. BROECKER. I may be repetitive, but I think that we must do everything to eliminate frivolous additions of greenhouse gases like the freons, to conserve energy, anything we can that doesn't strike to hard at our agriculture economic base. But I think that it is important, in all these environmental problems, that we establish a better understanding of what is going on. It is cost effective, if nothing else, you are going to save money in the long run, if you know more about how the systems operate.

I maintain that our country has done a very poor job of that, and the reason is fairly simple. The responsibility for basic research has been thrown in missions oriented agencies, which are pushed to do things immediately. If we then apply to those agencies to do long-term research, they say, we don't want to support that, we have to have short-term answers. If you go back to the agencies that support long-term research, then they tend to say, we don't have enough money for that, that is being supported by the mission oriented agencies and, therefore, go back to them.

So the very thing that we need most has fallen into a huge crack, and this crack is especially deep in areas like soils, groundwater, areas that don't have a traditional strength. It is not quite as back in oceanography or meteorology, which are especially strong fields and get support. I think that in most of these areas, the things we need far exceed our capacity to get them right now. NASA should be spending far more time looking down at the earth than looking at Uranus, and so forth. These are things that we can do, at a reasonable cost, that will have a very large long-term payoff, and save money on foolish strategies, which we are not doing now.

Senator BURDICK. What your answer indicates to me is that there is still something to be learned before we do something about this, is that right? Do we need more research?

Dr. BROECKER. I think what we have to do is build this knowledge base, because you are going to be coming back to us in hearings like this in 1990, and in the year 2000, and in year 2010, with the hope that, each time we come back, we are much wiser and we have better answers.

I maintain that in many cases we are just spinning our wheels trying to get quick answers, and the money is just going down the tubes and being lost. Whereas, if we took a more patient approach, realizing that the answers are not going to come quickly, and accepted that, and built some strength into those programs, then each decade we could give you better answers.

We can't promise success, it would be like saying that we can understand how to control or cure AIDS, or something like that. It is just something that the research people do their best, but we had better put some more effort into it.

Dr. CICERONE. Senator Burdick, in addition to being patient with us, I think, though, that you have to do some things to buy time, and that is where some of these relatively easy options could be contemplated.

We should look very carefully at how we can limit carbon dioxide emissions into the atmosphere by better energy conservation worldwide. There are easier steps on chlorofluorocarbons that could be taken, especially internationally, and encouraging industry to come out with substitutes that will have less of these effects.

These things can be done now. For example, in the late 1970s, this country, and others, made some very intelligent choices, getting rid of the less essential usages of fluorocarbons. Nothing was done to touch the refrigeration industry, but we eliminated spray cans of catnip and Martini glass chillers, and other products including deodorants and hairsprays, which the public judged to be non-essential. We can continue those kinds of actions as far as the less essential usages of some of these chemicals.

Senator BURDICK. Do the other two members of the panel have any suggestions, other than energy conservation, as to something that we can do now?

Dr. WIGLEY. I would just like to support what the panelists have said. There are things that can be done with regard to CFCs and energy conservation. Let me put a little perspective on this and say that the USA, although perhaps it has not done as much as could be done or could have been done, the USA has still taken a lead role in these environmental problems.

The CFC legislation in the 1970s is an example, and I think that some of the relatively short-term programs that have been developed over the last ten years are USA instigated. What I think is needed is a little more pressure from the USA to make sure that other countries follow this leadership role.

Senator BURDICK. Do you have any suggestions to offer on this problem?

Dr. RAMANATHAN. I essentially agree with what Dr. Cicerone said. I just want to add a little more to that.

For the next five to ten years, we will be working with circumstantial evidence.

The field itself, in terms of us predicting climate change, is very young, hardly five to ten years old, and suddenly the technology in its capability to pollute the atmosphere is far ahead of our scientific understanding of the atmospheric effects. You are asking us to answer questions which we are scientifically unable to do. I personally see a scientific urgency, as well as a practical urgency, to close the gap in our understanding.

Senator BURDICK. Thank you.

Senator MITCHELL. Thank you, Mr. Chairman.

Senator Stafford.

Senator STAFFORD. Thank you, Mr. Chairman.

I would have to make the observation that if we are going to be revisiting this matter in the year 2010, it may be appropriate, but it may be difficult for Chairman Burdick and I to make that revisit.

Because of the testimony that we have been listening to, let me ask any member of the panel to respond to this question.

What level of confidence do you have in the projections that we have been hearing? Would you say that it is 50 percent certain that the earth's temperature is increasing, and the ozone layer is thinning, or would you say some other figure like 90 percent, or maybe it is only 25 percent?

Would you give us what relative confidence you have in what we have been discussing this morning?

Dr. WIGLEY. Senator Stafford, in my view, it is 100 percent certain that the Earth has been warming over the last 100 years. I don't think that there is any doubt at all about that, and I don't think that there is very much doubt about the magnitude of the warming either. It is substantial, and it is almost one degree Fahrenheit over the last 100 years.

The leading question is the magnitude of the future warming in the coming decades. I think that if we look at two decades ahead, it is 80 percent certain that there will be substantial warming in the next couple of decades.

Senator STAFFORD. By substantial, what would you mean, a half a degree or a degree?

Dr. WIGLEY. Yes, I would say that by substantial I mean on the order of one degree celsius.

Senator STAFFORD. Is there disagreement on the panel on this?

Dr. BROECKER. I might state it another way, though. I would say, focusing this on the temperature effect of these things is a bit misleading. I would say, if you asked me what impact is this greenhouse buildup going to have on the wildlife 45 degrees north lati-

tude, I would say that there is a 95 percent chance that it is going to have a very major impact on that wildlife community because of the climate changes.

Senator STAFFORD. Dr. Cicerone?

Dr. CICERONE. There are other things that can affect climate. For all we know, it is going to get cooler due to other external effects of volcanoes. But everything equal, I think that the odds are well over 50 percent that we are going to see an increasing warming in the next decade.

As far as the ozone depletion, we didn't predict the Antarctic ozone hole. There is always room in these theories and models for uncertainty in both directions, but we always try to say that we hope we are overestimating the effects, but this time we may underestimate the effects. Again, I would say that ozone depletion is probably underway, probably with over 50 percent probability.

Senator STAFFORD. Just one more question to the panel again. Has life on the earth as it has evolved experienced an environment like the one that we are looking at in the next 20 to 30 years?

Dr. BROECKER. It certainly has. We are living in a particularly cool time now. We estimate that 100 million years ago, the temperature of the planet may have been 10 to 20 degrees warmer. So we have lived in warmer times. I don't think that anybody is saying that this is going to be devastating.

Senator STAFFORD. I would assume that this may be the first time that there has been a hole in the ozone layer.

Dr. CICERONE. We don't have any direct evidence. Ozone was discovered in the atmosphere in the 1880s. We think that it has been there for several hundred million years. It evolved along with oxygen. Before that time, it is difficult to understand how any complex life could have existed in that ultraviolet that would have been coming in.

There just isn't any evidence, we have to guess that this is the first change like this in the last several thousand years.

Dr. WIGLEY. I would add one clarification to what Dr. Broecker said. It is true, if you go back in time, to millions of years ago, you can pick up one analogue. What is the question here is that we are trying to make a change in terms of centuries, and not millions of years. This rate of change may be unprecedented. What is of concern is the magnitude, but also the kind of change of magnitude.

Senator STAFFORD. Thank you very much.

Mr. Chairman, this concludes my questions. I am required to meet an Italian Delegation, headed by their Foreign Minister. I wonder if you would indulge me to make a one-minute statement for the next panel.

Senator BAUCUS. Please go ahead.

STATEMENT OF HON. ROBERT T. STAFFORD, U.S. SENATOR FROM THE STATE OF VERMONT

Senator STAFFORD. Thank you, Mr. Chairman.

Before the next panel begins, I would like to welcome them to this meeting, but express my regrets that Administrator Lee Thomas is not with us today. I understand that one reason he is not attending is a policy of the Administration that administrators

and cabinet members apparently do not testify before subcommittees, only full committees.

However, since he is unable to be here, I can express a personal view which I hope I share with other Members of this committee, that I would rather have no international agreement at all than one which is bad. If other nations fail to act on this issue, it seems obvious to me the United States and a few like-minded nations may have to proceed unilaterally. We are after all, in this Nation, the world leaders.

Thank you, Mr. Chairman.

Senator BAUCUS. Thank you, Senator Stafford.

Dr. Broecker, in your written testimony, you discuss some effects of the deep ocean currents. Would you very briefly tell us what that is?

I think that you mean, mainly, is there are a lot of global warming studies that need additional resources to understand. I hear that the United States Government spent about $100 million in science on greenhouse gases and ozone depletion, but not very much on the effects of global warming.

You mentioned what global warming would do to certain wildlife at a certain latitude. Would you tell us whether we should redirect our focus here to encourage expenditures on science of chemistry, physics, and all of this, but also on the effects of some of these phenomena, particularly the deep ocean current phenomenon that you discuss in your prepared testimony?

Dr. BROECKER. I think that the deep ocean current effect is in the mainstream of science, and that that kind of thing is included. The value of the parallel climatic records is generally recognized.

Let me go back to the other side of your question first. You asked whether we are giving enough attention to the effects of some of these changes. One of the problems with those who want to explore the effects is that we do not give very concrete scenarios because the uncertainties remain large as to what the effects would be in any region of the country—what the rainfall would be, what the soil moisture would be, and that kind of thing. People without a scenario tend to shy away from doing this kind of research.

It seems to me that one of the things that I don't see much being done on is developing a strategy of what do you do if there are serious wildlife effects. One of the things that you can certain do is think of strategies for at least keeping every organism that is threatening the wildlife, such as finding the habitat that it can live in in a natural way. There is some of that being done now. I would think that more could be done along those lines than is being done. It is a difficult area to work in.

Going back to this ocean current, the reason I brought it up is that it is a beautiful example of linkages in the system. I show a diagram in my testimony that the water, like a conveyor belt, runs up to the surface of the Atlantic toward Iceland then it sinks, runs along the bottom of the Pacific and then comes back up to the surface, and the Pacific runs toward the equator.

Senator BAUCUS. The first question is, after the completion of the Antarctic Survey, how much will we know of the causes of the ozone hole. Then the next question is whether there are any indications of a widespread global problem.

Dr. CICERONE. Do you mean how much more will we know next?

Senator BAUCUS. Compared to what we know now. Do you think that the study is sufficiently financed and thought through that we will have the data, and we will be in a significantly better position to take action compared to today?

Dr. CICERONE. There are a lot of very thoughtful ideas that have come forward on why this can be happening, why the timing is such and such over a number of years, and why it gets worse every year, or at least it maintains at the same pace. These ideas have some parts to them. We have clear indications of what should be measured, and it turns out that we know how to make the measurements for the various chemicals, and the atmospheric properties that are involved in these theories.

I don't know if the operation is well-enough financed. It is supported by NASA, the National Science Foundation, NOAA, and I think there is even some chemical industry support. My preliminary indication is that every dollar that will go into those expeditions will come out of other related research support, so it is a zero-sum game.

There are testable things that can be measured to sort out these theories, and it is the sorting out that is important to allow us to know whether or not the to effect is going to spread and worsen, or stay self- contained.

I don't think that we are going to have the answer from last August's, September's, October's or November's data. I think that next year's expedition will probably triple the chances of a useful explanation compared to last year, but it may still take a couple more years.

Senator BAUCUS. I understand that this last expedition has allowed us to make a major step forward in our understanding. A major effort went into this last study, and there should be a far better explanation than there is today.

Dr. CICERONE. Yes, and the scientists who went there, I think that it is important that I mention, are to be congratulated because nearly every piece of equipment worked under those very hostile conditions. So people came home with data, and they are putting it together. It puts a new set of constraints on what you might say is your wild theory or my wild theory. We now have more constraints to obey when we cook up explanations than we did a year ago.

Senator BAUCUS. Thank you.

Senator Gore.

Senator GORE. Two very brief questions. There were news reports a few months ago about the measurement of a rather large increase in the permafrost above the Arctic Circle. Are any of you familiar with that data, and would you characterize it as significant?

Dr. WIGLEY. Senator, I think that I can make a statement about that. I am not familiar with the particular details of this, except for what I have read in the literature. I should comment that it was not new information. We know that the Arctic is warming.

The information on the permafrost is only regional information, and regional changes are not necessarily the same as global changes. I would say that that particular piece of research received more publicity than perhaps it should have.

Senator GORE. It may not be that significant.

Dr. WIGLEY. That is precisely my point of view; I would agree.

Senator GORE. Does anybody else want to comment on that.

My next question then is that there has been much discussion about the uncertainties associated with the projections that you have given. Another way of stating it is that there is a certain chance that there will not be that large a warming as you are projecting.

Isn't it true to say that there is also uncertainty on the other side, and that there is a certain chance, perhaps equal to the uncertainty on the saving side, that the warming involved could be larger or more than the mid-range projections. If, for example, the ocean began to disgorge CO_2 as a result of warming, rather than absorb it at a higher rate?

Dr. BROECKER. Yes. The earth is sort of symmetrical. I mean, we don't know enough about it to say that there is any higher probability that we are going to go on the low side than the high side. I don't think that we can even make that spectrum very well.

I think that it is true, there is a chance, maybe 5 percent, that the warming will be so bad that the whole world would agree that this is a terrible thing, and we ought to try to go back where we come from, and I have pondered that. I have also written a paper, that is in my desk drawer, because I don't think the world is ready for it.

If you read the scientific literature, only one paper discusses what would you really do if it was really bad and you wanted to reverse it, and it was written by a Russian scientist named Budyko. He said that it was possible that you could take counter-action by increasing the reflectivity of the earth, and he suggested adding SO_2 to the stratosphere.

Dr. BROECKER. You are talking about a desperate situation, and he certainly made the point, and we checked his calculations, that it is possible to reverse it with an expenditure of something like $20 billion a year, but that particular one would have vast consequences in air chemistry, and so forth.

The interesting thing is that this is an area, an unknown area for scientific research. I think that it is, I think, equivalent to studying racial intelligence. People don't want to hear about scientists monkeying around with large scale weather modifications, but we are doing scale weather modification with CO_2, and we have to.

It is an interesting subject. Should we encourage thoughts about taking on insurance policies against that very few percent, or things would be so objectionable that it would affect our food production in such an adverse way that we would say, we have to do something, people are starving, to bring that temperature down.

It could be done but, as I said, there has been one paper on that, and there are about two million on the other aspects of the problem.

Senator BAUCUS. Senator Pressler.

Senator PRESSLER. I had to be at another hearing, and I apologize.

From your scientific point of view, what would be the significance if the United States were to act alone in banning more of the CFCs?

You are a scientific panel, and I guess what we are really getting at here is what our position is because it is so confusing. As I see the legislative alternative facing this committee, it is for the United States to act individually as a country in banning more of these products, or to try to have a freeze.

I understand that everybody wants a treaty that is idealistic, and so forth, but I understand that we have taken some steps that other countries have not taken, such as banning aerosols. Other countries have set levels, but they are still high.

Legislatively, if we are faced with acting alone, would one country's actions be enough to make any difference in the scientific phenomena that you have described?

Dr. CICERONE. There is a different aspect today than there would have been ten or twelve years ago. The United States, ten or twelve years ago, represented over half of the world's usage and discharge of fluorocarbons into the atmosphere, and today the U.S. is less than half. The rest of the world usage has gone up. The usage pattern has changed. In the United States, aerosol propellants use is way down, but it continues elsewhere.

To give a detailed answer, the good news is that we know enough about where these chemicals are coming from, and we can make projections into the future that show more growth in the other countries than in the United States. So to be strictly arithmetical about it, the United States is still the largest individual nation user, but less than half, whereas ten years ago we were more than half.

Whether Senator Stafford's scenario would work, if the United States would simply be a leader, with the others following, I think is the key question in an international agreement.

Senator PRESSLER. Would it be a sufficient correction if the United States did it alone?

Dr. CICERONE. I see what you are saying. It would buy time. Lopping off several hundred thousand tons of emissions a year of each of these chlorofluorocarbons, if the United States just stopped, would buy us more time. But there would be some period, at some date in the future, where we would be back pretty much where we started, if the rest of the world continued to grow in these emissions.

Senator PRESSLER. I know that recently it was found that the United States doesn't export or is not a major exporter to East Germany or Czechoslovakia, and there is almost as much of it around.

The products that could be substituted for CFCs, would they also have a bad side effect?

Dr. CICERONE. Some of the substitutes also have bad side effects, but compared to the fluorocarbons that we are using right now, they would be much, much less harmful, perhaps a factor of a hundred or more in some cases. Again, we would buy an awful lot of time.

Going back to one of Senator Baucus's initial comments about what it takes to keep the nation competitive in anticipating the future, if our producers could come up with useful substitutes,

which I think they are well on the road to doing, and if later on the rest of the world would catch on to the wisdom of the option, we could be in the driver's seat from the production point of view as well.

Senator PRESSLER. On the other hand, if we do not come up with these substitute products, the rest of the nations continued to use the CFCs, we would be in a weaker competitive position at least for a time.

Dr. CICERONE. Exactly. We would simply lose the business, I presume.

Senator PRESSLER. So this is really competitive as well.

The bottom line is that you do feel that we should go forward, individually as a Nation, if we don't get these treaties at this time?

Dr. CICERONE. No, I wouldn't say that.

Senator PRESSLER. What exactly would you recommend?

Dr. CICERONE. I would favor pushing very hard for an international agreement of some kind.

Senator PRESSLER. Does anybody else want to respond to that?

Senator BAUCUS. Thank you, Senator Pressler.

Thank you, gentlemen. We appreciate your testimony very much.

The next panel will include John Negroponte, Assistant Secretary for Oceans and International Environmental and Scientific Affairs, who is accompanied by Ambassador Richard Benedict.

In addition, the panel includes Mr. J. Craig Potter, Assistant Administrator for Air and Radiation at EPA, and he is accompanied by Mr. Fitzhugh Green, Associate Administrator for International Affairs, and Dr. Vaun Newill, Assistant Administrator for Research and Development.

We appreciate your patience, gentlemen.

Secretary Negroponte, why don't you proceed first.

STATEMENT OF HON. JOHN NEGROPONTE, ASSISTANT SECRETARY FOR OCEANS AND INTERNATIONAL ENVIRONMENTAL AND SCIENTIFIC AFFAIRS, DEPARTMENT OF STATE, ACCOMPANIED BY RICHARD BENEDICK, DEPUTY ASSISTANT SECRETARY FOR ENVIRONMENTAL AFFAIRS

Ambassador NEGROPONTE. Thank you, Mr. Chairman.

I have a prepared statement that I would like to introduce for the record, and perhaps I could make a few brief remarks, with your permission.

I appreciate the opportunity to meet with you today. On my right is my Deputy Assistant Secretary for Environmental Affairs, Richard Benedick, who is the lead negotiator in the international process addressing protection of the stratospheric ozone.

The United States and other nations are engaged in a historic cooperative effort to prevent the potentially serious effects from the depletion of stratospheric ozone. We began the convention for the protection of the ozone layer as an important first step, but as many of the members of the committee noted, speaking in favor of ratification of the convention, additional measures are necessary.

We are now engaged in negotiations under the auspices of the U.N. Environment Programme, that is, UNEP, on a protocol to the

convention which provides for regulatory controls on ozone depleting chemicals.

Between the adoption of the convention in Vienna in March of 1985 and the resumption of negotiations on control measures in December of 1986, the international community participated in a unique cooperative effort to improve common understanding of the nature and impacts of the ozone depletion issues.

The United States Government played a leading role in that process. At the same time, U.S. Government representatives were working bilaterally with various governments to improve the understanding of the nature of the problem and the options for reducing risks. This extensive multilateral and bilateral effort is described in more detail in my written testimony.

The United States Government believes that early and concerted action by the international community is required to protect stratospheric ozone. In the current negotiations, we seek agreement on the following broad objectives:

First, a meaningful near-term first step to reduce the risk of ozone depletion and associated environmental and human health effects.

Next, a long- term strategy and goals for coping with the problems successfully.

Third, a carefully scheduled plan for achieving the long-term goals, including periodic reassessment and appropriate modification of the strategy and goals in response to new scientific, technical, and economic information.

To achieve these objectives, we have proposed a protocol text which would provide for, first, a near-term freeze on the combined emissions of all ozone-depleting chemicals. Next, a long term scheduled reduction of emissions of these chemicals down to the point of eliminating emissions from all but limited uses. Third, periodic review and assessment.

We have come a long way since March, 1985, in Vienna. In Geneva, last month, representatives from all regions agreed that new measures must be taken to control emissions of ozone-depleting chemicals. However, differences over the scope, stringency, and timing of control measures remain.

The U.S. delegation focused, in the first round, on seeking support for the basic elements of a protocol which would have both near and longer term measures, cover a broad spectrum of ozone-depleting chemicals, and contain good scientific assessment and technology incentives.

Among the participants, Canada and the Nordic countries advocated strong and early action. The European Community, Japan, and the USSR acknowledged the need for controls, but do not yet support the long term measures, full coverage, and trade provisions we believe are necessary to make the protocol effective.

Looking ahead, the United States will continue in the next round of negotiations, which are scheduled for February 23rd to the 27th, to pursue the objectives I have outlined. We are consulting actively with a number of nations in the interim through discussions with environmental, foreign ministry and trade officials in Washington and abroad, through our embassies, official visits, and scientific exchanges.

This is a difficult and complex negotiating process. We have made substantial progress, but we have a long way to go to reach an effective agreement with broad participation. Meanwhile, we must be sure that our actions domestically support and do not undercut that international process, since this is clearly a matter which the U.S. cannot resolve alone.

We have entered a new era of truly global environmental management in which we are all made more conscious of the unity and vulnerability of our planet.

I would just like, by way of conclusion, Mr. Chairman, to address one question, which has been alluded to in several instances earlier in this hearing, and that is the question of whether we would go it alone, so to speak, if our international efforts were to fail in some way.

I think that the first answer to that question is, of course, that we are going to try. I think we have had some encouraging progress in our talks and we have come quite a long way since the signing of the convention in 1985. We are encouraged by the progress to date. I think that other countries are moving in our direction, and we think that is good.

Secondly, I would like to say that one of the issues that we would have to address, if we failed in our international efforts in some respect, which is a proposition I do not accept, but if we were to do that, one of the questions we would have to address is whether additional measures on our own part would simply move the problem somewhere else on this planet.

Would industry just move to other countries that would not take these stricter control measures, and would we, in effect, be simply encouraging other countries to feel that, absent United States production, they could not only not curb their production, but perhaps increase it to make up for the gap that was created by the suspension of United States production of CFCs.

It is a complicated question, one I hope we won't have to address, but I don't think that there is any easy answer to it.

Thank you very much.

Senator BAUCUS. Thank you very much.

J. Craig Potter.

STATEMENT OF J. CRAIG POTTER, ASSISTANT ADMINISTRATOR FOR AIR AND RADIATION, ENVIRONMENTAL PROTECTION AGENCY, ACCOMPANIED BY FITZHUGH GREEN, ASSOCIATE ADMINISTRATOR FOR INTERNATIONAL ACTIVITIES; AND DR. VAUN NEWILL, ASSISTANT ADMINISTRATOR FOR RESEARCH AND DEVELOPMENT

Mr. POTTER. Good morning, Mr. Chairman.

Needless to say, I welcome the opportunity to discuss these issues with you. I commend this committee once again for its efforts in this area.

With your permission, I will just ask to enter my written testimony into the record, and I will summarize it.

With me, this morning, I have Fitzhugh Green, Associate Administrator for International Activities, and Vaun Newill, Assistant Administrator for Research and Development. Our direction from

the Administrator has been to place these issues among the Agency's highest priorities, and together our offices spearhead EPA's efforts to understand and respond to these concerns.

As Lee Thomas said in his statement before this committee last June, this remains a vitally important issue. It is an issue that has gained a good deal of appreciation in the last several months, and one to which EPA has devoted and is continuing to devote considerable effort. With regard to those efforts, we have come a long way since June of last year.

Our efforts began in January of 1986, about a year ago, when we announced our stratospheric ozone plan, and set forth an agenda for dealing with the domestic and international aspects as well. There are a number of specific actions the United States has initiated to educate and encourage other governments to support reductions of CFC use.

They range all the way from a leadership role in ratifying the Vienna Convention to cosponsoring workshops and international conferences. I go into this in detail in my statement. They all underscore the importance we attach to a global solution of what is truly a global problem.

Ambassador Negroponte has discussed the current status of our international negotiations in greater detail. Let me just say that the U.S. position—a near-term freeze followed by a scheduled long-term reduction of CFC emissions and use subject to a periodic reassessment of the science—has had the effect of altering the tone and content of the negotiations.

We are now working hard to maintain the momentum and to broaden the level of international awareness and cooperation. We are looking to create and seize new opportunities to engage other nations in the discussion of the science of ozone depletion as well as measures needed to deal effectively with the problem.

On the domestic side of this issue, we are also moving forward rapidly. While we hope that we are able to reach a satisfactory international resolution of this issue in the near term, we recognize that we face an obligation under the Clean Air Act to assess the need for further domestic regulations.

I can't predict the outcome of these activities, but I can state that we are committed to meeting the time frames that we have laid out. On the science, Mr. Chairman, which must underlie decisions that are made in the international and in the domestic arenas, we are engaged in finalizing the risk assessment document that should contribute substantially to a better and more comprehensive understanding of the science.

In conclusion, I would like to make three points.

We have been engaged in a coordinated effort to elevate international concern about the risks and the seriousness of this problem for the last several months that has now gone well beyond what we envisioned when Lee Thomas spoke to you in June.

Because of his commitment on this issue, I expect that you will see personal interaction between the State Department and their counterparts, but also between the Administrator and his counterparts, particularly in the community of users as well as producers worldwide. This will occur primarily in the time frame between now and April.

We need your support, Mr. Chairman, in that endeavor. It will in no way detract from our domestic regulatory efforts, at the same time, we all need to recognize that no single country so dominates the emissions or the utilization of these chemicals in such a way that it can solve this problem alone.

The second point that I would make is that while we might argue about the consensus in characterizing the science, there are some key points on which it is fair to say that consensus exists.

First of all, it exists with regard to basic science in terms of the interaction between the CFCs in the atmosphere and their effects on ozone.

Secondly, consensus currently exists on the increasing levels of production at the present time and the certainty that if we put enough chlorine in the atmosphere depletion will occur.

Thirdly, there seems to be consensus that the risks here are substantial enough that we must take concerted action. The debate, I predict, will be over how much and where that action will take place.

In that regard, I envision an interactive and somewhat formalized process in the very near future with industry, as well as the environmental community, with regard to international efforts, as well as with regard to our domestic efforts. A very key component will be our risk assessment document, once it is peer reviewed by the Scientific Advisory Board. I know that they have been meeting, just as we are. I know they were scheduled to meet in the last couple of days on this issue.

Another key, I think, is the process that we will engage in, both domestically and internationally. We are going to be walking a fine line between balancing technology forcing actions and potential economic disruption.

This is the final point that I think Lee would want me to make. The principles that were established by the Administrator and the State Department have not been compromised, in my view, in the international arena.

The principles, I would just reiterate again, are basically a freeze at or near current levels; some sort of a process to deal with long-term emissions; and, finally, the process of reassessing the science and to reassess the protocol as we know more about the issues.

This is an interactive process, and it is important that we recognize that there will be a great deal of give and take, but I would hope that we could encourage that process and work with this committee in doing so.

Thank you.

Senator BAUCUS. Thank you, Mr. Potter.

Senator CHAFEE. Thank you, Mr. Chairman.

You weren't here when we made our opening statements, but I want to congratulate you for holding these hearings, along with Senator Mitchell, and your effort along this direction.

Mr. Ambassador, in your statement, I know that your view is that if we attempt to proceed alone, the others won't follow, and they might even proceed to fill in the slack that we made. I suppose that you could point to the aerosol situation by saying, look, we did all that, and none of these others did anything about it.

It seems to me that we are embarking on a very, very long-term effort, a commendable effort, but a long-term one, and I have the feeling that we ought to do more ourselves, as I said in my opening statement. Indeed, it seems to me that in these international negotiations, the United States seems to have backed off from its tough position.

Let me just take two documents. I have one here from the Department of State, dated November 5, "The outline paper outlines principles for an international protocol," and it says that "the first step is a near-term freeze on emissions; the second, a long-term phase out."

But then, when we got to Geneva, the Government of the United States had changed its position. It was no longer a near-term freeze, but it was a meaningful near-term first step to reduce significantly. Step two was no longer a long-term scheduled phase out, but it was an agreement on a long-term strategy and goals for coping with the problem. Frankly, I think that we have to push you folks and, if this fails, go it alone.

Here is my question. Suppose we went it alone and we said that we are going to ban certain CFCs, and we reach way out through our trade laws; it is not just a question of somebody overseas introducing it. We have trade laws that will ban not only the imports of those particular CFCs, but we have stretched even further and banned certain cleaners with CFCs.

Why do you think of that?

Ambassador NEGROPONTE. I wouldn't presume to try to influence our domestic policy in that way, Senator. My point was that we have come quite a long way, and rather rapidly, considering that in 1985 we had simply signed a protocol that was basically designed to exchange information with respect to stratospheric ozone layer, and now in 1986 and 1987 we have already persuaded the international community that the time has come to act on the basis of the scientific information available, which is, I think, a significant international environmental accomplishment.

It isn't that we have in mind prolonged negotiations that we think will be interminable. We are trying to hold the international community to a serious negotiating schedule. There is some resistance to meeting again in February, because some of the participants in the negotiations want more time to formulate their positions. Working with the U.N. Environmental Programme, we brought these other countries around and they have agreed to another round of talks.

As for our position, I would not agree with the characterization that we have watered it down in any way. Our basic position remains to work for a near-term freeze, and then some kind of phase down. In fact, the draft text that we left in Geneva at the last negotiating round starts out with a proposal that would in X years after entry into force of the protocol, each party shall ensure that its aggregate annual emissions of CFCs does not exceed its 1986 level.

In other words, some kind of a freeze. Then we would propose a 20 percent reduction after so many years, and then 50 percent, then 90 percent. Those remain our negotiating goals. Exactly what will come out as a result of the negotiating process, I can't be cer-

tain at this time, but we are giving it our best shot. As said, we are making some progress.

Senator CHAFEE. I appreciate the efforts that you are both making. I think that it is extraordinary that we have come as far as we have; we are in a tough league. I think that it is easier to get people to agree to do something than to have them do it. You have done the first part.

Why haven't they done something on aerosols, that is easy.

Ambassador NEGROPONTE. Perhaps I can defer to Ambassador Benedick on this one.

Senator CHAFEE. All right, Mr. Ambassador. I think even economically it is justified.

Ambassador BENEDICK. I think that it is important not to underestimate the extent in Europe to which this issue has not exactly caught the imagination of the general public.

Senator CHAFEE. It caught the imagination of the United States public.

Ambassador BENEDICK. There was enough publicity in the newspapers and elsewhere. In fact, in 1970, we were considering a ban on the use of CFCs in aerosol products. In fact, the American consumers themselves, without the ban, began to reduce their consumption of aerosol products. In other words, they were ahead of the official Federal ban. There was a great deal of consumer awareness here in the United States ten years ago, which is not the case in the rest of the world.

We are trying to remedy that. The United States Information Agency has organized programs and broadcasts, in which the National Aeronautics and Space Administration has participated in five European cities, to try to get the information out. They were very well attended. We are working on other fronts as well.

We must not underestimate the strength of the European chemical industries on the environment. There is no countervailing force; consumer groups and environmental groups have simply not taken up this issue. The chemical industries are stressing the costs to them in terms of production adjustments.

In the case of aerosols, I would just like to point out that the European substitute for CFCs is a flammable product. In the United States, most of our factories are outside of cities. The structure of European industry is such that the filling of the aerosol cans takes place in areas within cities, because these are small operations. For them to go over to a flammable substitute in the process of filling the aerosol cans involves risks. To make the adjustments would be very costly in terms of these small operations.

Senator CHAFEE. Mr. Ambassador, that business about filling cans in the middle of a city, you and I discussed that before, and it is an intriguing thing. I can't believe that a German chemical plant is squeezed in the middle of Dusseldorf.

Senator BAUCUS. Senator Mikulski has now joined us.

Senator, do you have a statement?

Senator MIKULSKI. Thank you, Mr. Chairman. I am just listening. I really enjoyed the colloquy that just occurred. I do have some questions.

In terms of the next round of negotiations that will occur from February 23d to the 27th, what do you believe you will be able to accomplish in those negotiations?

Ambassador NEGROPONTE. If I could ask our negotiator to answer that question.

Ambassador BENEDICK. In the first round of negotiations, Senator, in December, I think we made a substantial amount of progress compared to where we left off in March of 1985 in Vienna. Since that time, almost all of the countries, at the meeting in December, did agree that some kind of a near-term freeze was required.

I think that a consensus is beginning to gel around the idea of a near-term freeze on the production or emissions of CFCs. Where there wasn't a consensus was the next step. As we pointed out, the second element of the U.S. position was a longer-term strategy leading to a reduction. This was not agreed to generally. The third element is a periodic reassessment based on the science, and this did have a lot of consensus.

We will work together to get a greater acceptance of a near-term freeze of the chemicals, a phased reduction, and also build into it a strategy for a gradual reduction, so the CFCs will be gradually disappearing. We will encourage them to do the research.

Senator MIKULSKI. What are the options for some of the countries, will they be able to change their industrial activities?

Ambassador BENEDICK. As I said, in the European Community, there is a lot of resistance. Unlike the United States, they have not seen it as a problem, and the costs involved in reduction are too great. They are echoed in this by the Soviet Union and Japan.

We are chipping away at this. We are sending next week a special scientist to the Soviet Union to meet with Soviet scientists on a scientific level. We are also sending a special scientist to Tokyo. We are trying to work with those countries.

I know you appreciate that the United States has some interests in international negotiations, especially around complex scientific and trade issues such as this one, where there are still ambiguities in the science. We have our paper on the table, and we are working toward what we hope will be a good agreement.

Senator MIKULSKI. Is there genuine and authentic searching around? Are you thinking that we still need more information?

Ambassador NEGROPONTE. I think, in the case of ozone depletion and chlorofluorocarbons, there is growing international acceptance of the scientific certainty, and it is really the economic dislocation issue that concerns the countries.

Senator MIKULSKI. What are we doing about developing substitute technologies in our own country?

Mr. POTTER. I alluded in my statement to the efforts to interact in a somewhat formalized way with the industry and the environmental community as we work through this process. Part of the notion behind that is that we can truly get behind what they know about what substitutes are available, and how readily available they are.

This may be a question you might want to pursue later with the other panel as they come up. But we are engaged in an effort, and I think that it is important to focus on this, because it is a some-

what painful process, of understanding exactly what substitutes are available, and balancing the desire to avoid economic disruption against the desire to push technology as far as we can. The issue, of course, is how far do you go.

Senator BAUCUS. My assessment is that there ought to be a standard flowing out of their efforts. I think also the point should be made here that there is an opportunity for us to develop a very viable product, a substitute, which will enable us to exercise the leadership that we will need. Why can't we be creative and stronger in order to accomplish the needed purpose here?

Ambassador NEGROPONTE. My answer to that would be, Senator, first of all, there is no doubt that our approach is essentially a positive one.

Senator BAUCUS. It has to be more than essentially positive. It has to be very positive.

Ambassador NEGROPONTE. This is a major, global environmental initiative on our part. We are seeking to reach an agreement internationally on a set of controls that would limit production, and eventually phase out production of these products. I can't think of any other similar examples of environmental negotiations of such global importance.

Secondly, not only are we trying to discuss this through the negotiating process, but we have also mounted the public affairs efforts to which Ambassador Benedick has referred.

Finally, I think the pace of negotiations is, in part, simply dictated by the fact that we are dealing with a whole multiplicity of governments. To have talks in December, and then agree to meet again in February, I don't think that this is too bad a record in terms of a rather large multilateral negotiation.

I would just say, by way of a reply, that we give this issue high priority. We understand its importance and urgency, and I think that we are moving to take concerted international efforts.

Senator BAUCUS. How much opportunity have you had to establish the validity of the Dusseldorf claim of the flammable process? How much opportunity have we had to establish the validity of that claim?

Ambassador BENEDICK. I am not sure that we have had any opportunity.

Mr. NEGROPONTE. I think that if you look at the EC's position now, it now appears to be ready to agree to an initial short term freeze. They are saying, let us decide between ourselves.

My position is that they seem to be prepared to accept the freeze, but what it is going to mean to them is going to be different. We are not now attempting to dictate to them. If we can establish a ceiling on both production and total uses, we will have accomplished quite a lot.

They are saying that they can agree to a near term freeze. They haven't ruled out a long-term reduction, but I think that their position now is, let's have a near-term freeze now, and let's examine what the situation is in a few years.

Senator BAUCUS. The position that they are taking now, in how many years?

Ambassador NEGROPONTE. Again, this is really, in part, going to be dictated by considerations of negotiability, but as a goal we would say 20 years.

Senator BAUCUS. For elimination?

Ambassador NEGROPONTE. Yes.

Senator BAUCUS. Senator Mitchell.

Senator MITCHELL. I have no questions.

Senator BAUCUS. Senator Gore.

Senator GORE. Thank you, Mr. Chairman.

If we have a freeze, how much of what is in the atmosphere would be retained?

Mr. POTTER. The levels that we are looking at now and discussing in the risk assessment, I may have to turn to the scientists on this, but I think it would probably be in the neighborhood of half for CFCs, with the caveat that you mentioned earlier, that the reduction is 85 percent.

Secondly, we will be meeting this afternoon and discussing this and reviewing it in detail at that time, but the approach that we have taken there is a wide range of scenarios based on the demand, the historical relationships with economic activities and the use of these chemicals, and then following the effects over time. We have a high degree of statistical uncertainty that we are going to be dealing with. It is probably not appropriate for me to say what it is exactly.

Senator GORE. You state in your paper that an 85 percent reduction worldwide would be required to maintain the current level of atmospheric CFC.

Mr. POTTER. That is one range in the scenario that we are looking at. Perhaps, I think, that as the immediate process——

Senator GORE. I know that it is pending review. It will require 85 percent reduction worldwide emissions to maintain the current concentration of CFC in the atmosphere. If the Antarctic Study comes back and demonstrates that, yes, this is the probable cause of ozone depletion, and, yes, there are good reasons to believe that it will get worse.

Mr. POTTER. If we conclude that we can extrapolate what we have seen with regard to the ozone hole over to the overall stratospheric ozone situation, we will really have discovered something. So far, we have not come that far. Nothing that we have looked at statistically or modeled with regard to the stratospheric ozone issue predicted anything like the ozone hole.

We need to recognize that there are very peculiar characteristics in the South Pole area, unlike anywhere else, in terms of temperature, in terms of darkness. The physics of the chemistry are very limiting and different from what they are anywhere else.

So while it is a very important thing to look at, we don't know that it has any direct relationship to what is actually happening to the stratosphere.

Senator GORE. Do you have authority, under the treaty authorization to include other ozone depleting gases in the future.

Ambassador Negroponte. Yes, Senator, we do.

Senator GORE. I want to reemphasize something that Senator Chafee has taken the lead on, and that is the frustration that we have experienced. Is it correct to state that each country is resist-

ing for different reasons? Europe is most recalcitrant because it doesn't want to change any of its CFC use. Japan is most interested in protecting its use of CFC 113 for the computer chips, partly as a strategy for dominating the world semi-conductor market. The Soviet Union is trying to protect its future rights to be a high tech player. Is that a fair summary of the situation?

Ambassador Benedick. Yes, Senator, it is a fair summary. Once again, there has been progress in that area.

Senator GORE. Thank you, Mr. Chairman.

Senator MITCHELL. Thank you, Senator Gore.

Thank you very much, gentlemen, for your testimony.

The next panel consists of Dr. Gordon McDonald, Dr. Jessica Tuchman Mathews, David Doniger, and Richard Barnett.

Let's have order in the room, so that we can proceed with this panel.

Thank you very much for coming. Let me remind the witnesses that their statements will be inserted in full in the record. I ask that you provide a brief oral summary of your statement, and then be available for questions. We are going to use this machine here, so when the red light comes on complete your summary. Thank you very much, and we will begin with Dr. MacDonald.

STATEMENT OF GORDON J. MacDONALD, VICE PRESIDENT AND CHIEF SCIENTIST, MITRE CORP.

Dr. MACDONALD. Thank you, Mr. Chairman.

First, I want to endorse the statements made earlier today by the panel of scientific experts. This is a field in which I have worked for over 25 years, and I found the testimony right down the line.

There is one point that I think requires further emphasis. The major effects of greenhouse gases is a global warming that we have been talking about, but accompanying that global warming may very well be an enhanced variability in the weather and climate.

The atmosphere ocean system as it shifts from one equilibrium state to another equilibrium state can undergo rather wide fluctuations. A poor but not totally irrelevant example or analogy is that of a basin with leaky plug and a leaky faucet. The level of the basement and the temperature remain about the same as the water seeps in, and a little seeps out. But conditions can change very drastically if you pull the plug and open the faucet, and rather than having just a drop fall into the basement and a small wave come out with each drop, you get the turbulent slosh as the system valiantly tries to achieve a new equilibrium.

In the case of the atmosphere and ocean, our new understanding of complicated dynamical systems suggests that this might be so. In fact, the drought in the Southeast this past summer was unprecedented, the Sahel drought of the past decade may be only the occasional ripple in our leaky basement, but alternatively they could be the beginning of the turbulent slosh when the plug is pulled due to the man-made addition of gases in the atmosphere.

Let me turn to your first question, which is which energy uses contribute to the greenhouse effect?

All carbon based fuels, coal, oil, natural gas, wood, contribute to the production of carbon dioxide. All of them also contribute in dif-

ferent ways to the production of other trace greenhouse gases. The inefficient use of fuel leads to a greater production of carbon dioxide per unit of useful energy.

The use of solar and hydroelectric and nuclear energy do not directly affect the composition of the atmosphere. The production of energy capacity may add some carbon dioxide, but basically these energy uses do not produce carbon dioxide.

Now to your second question. Are there differences in greenhouse gas emissions among fuels? The answer is very definitely yes. If you look at gasoline, the amount of gasoline to produce a million Btus of thermal energy, produces about 30 percent more carbon dioxide than the same amount of natural gas.

If you burn coal to produce that same unit of energy, a million Btus, you produce 75 percent more carbon dioxide than the same energy delivered by natural gas. The reason is very simple in the chemical sense. The amount of energy that you get out depends on how many hydrogens you have for each carbon, and natural gas has four hydrogens for each carbon, gasoline a little bit less than two, and coal a little bit less than one.

If we then look at what has happened in the recent past in this country, let's say, over the past ten years, we find that the energy mix is shifting in the direction of going toward that fuel that produces the most CO_2 per unit of energy delivered, coal.

For example, in terms of carbon dioxide, of the 4.7 billions of metric tons of carbon dioxide produced in 1975, 1.2 billion metric tons were produced by coal, 1.63 billion tons of CO_2 in 1985. I include in my written testimony a further discussion of that.

Let me just quickly touch on what can be done to control greenhouse gas emissions, which is your third question.

First, slowing will come about through more efficient use of energy. This is the primary way. A move away from carbon-based fuels can be stimulated by such measures as a user charge on CO_2. I was involved in a suggestion for a user charge on SO_2, some 15 years ago, which came to nothing, but I think that it is still something that we should carry in our bag of tricks because, both for the capitalist and socialist countries, the atmosphere is a free good, and they are not paying for its use.

In fact, the result would be an excellent revenue generator. A charge of $\frac{1}{10}$ of a cent per pound of CO_2 released would generate 10 billions of dollars a year, as opposed, let's say, to imposing import duties on foreign oil.

Another point is the whole question of the relation to acid rain. There are various proposals, including yours, Mr. Chairman, to reduce the acid rain by bringing down the levels of SO_2 primarily, but also the oxides of nitrogen.

There are two other gases that play an important role in acid rain and in the greenhouse effect, those are the organic carbons and carbon monoxide. I would argue that one should attempt to bring all four pollutants down, rather than emphasizing one, two, three, because of the interactive nature of the components.

I am going to turn to several specific measures that certainly go in the right direction. Energy conservation, maintenance of the national 55 mile per hour speed limit—this is perhaps the most cost effective energy conservation measure—maintenance of EPA stand-

ards on mileage for automobiles, increased use of natural gas—there are a number of steps which include repeal of the constraints in the Natural Gas Use in Power Plants and Industrial Fuel Use Act; the disincentives to natural gas use in the Natural Gas Policy Act; or to promote the use of natural gas vehicles in the way, for example, that New Zealand has done with singular success.

Finally, there is the potential for gas-fired co-generation, a very efficient and relatively pollutant-free way of generating energy. These are all small steps, these conservation steps, but they are important.

In the longer term, of course, we have to deal with it as an international problem, but I think the urgency of the problem is such that we cannot continue to wait on further research.

We must begin to make significant efforts to reduce the greenhouse gas burden that we are putting on this planet and for which not only our children, but our grandchildren, are sure to have to pay an increasing cost.

STATEMENT OF DR. JESSICA TUCHMAN MATHEWS, VICE PRESIDENT AND DIRECTOR OF RESEARCH, WORLD RESOURCES INSTITUTE

Dr. MATHEWS. Thank you, Chairman.

Let me mention that I am accompanied this morning by my colleague, Dr. Irving Mintzer, who is available to answer questions.

I would like to use these few minutes to make just three points.

The first is to try to answer the question for you, are there actions the U.S. can take now that will make a difference on the greenhouse warning? I believe the answer is yes, and I will try to summarize what they are.

Secondly, I want to address the question of whether these actions are justified now, given the present high degree of scientific uncertainty that we have talked about this morning. As responsible actors on the public's behalf, are you justified in pushing for action now, or is the path of greater wisdom to wait for more confident predictions? Again, my answer is yes. I think the time for action is now, and I will try to explain why I think so.

Finally, and in some ways I think the most important thing I would like to convey this morning is to point out the connections between the greenhouse warming and a number of other serious issues that are before this Congress, on which these same steps that I will describe would have a powerful positive impact.

These linked issues are: the near term likelihood that we are heading for another energy crisis; the longer term prospects for U.S. economic competitiveness; the third world debt crisis, which is temporarily off the front pages but still very much with us; and as Gordon MacDonald just mentioned, acid deposition and related forms of air pollutant damage.

Turning first to the question of whether there are actions, Gordon has mentioned several of them. They fall into three categories as you know: limiting CFC emissions; limiting overall energy demand; and switching to carbon-poor or carbon-free fuels.

Other witnesses will talk, I think on this panel, in more detail about the possibilities of limiting CFCs. I would just like to point

out that a recent study by the World Resources Institute found that there are opportunities to cut emissions by one-third within five years, that these are relatively cheap and easily accomplished. There is a table summarizing specifically what those cuts are attached to my complete written testimony.

Secondly, turning to energy policies, the core of a greenhouse mitigation strategy has to lie in a long-term, worldwide effort to reduce energy use and increase energy efficiency. The experience of the last 13 years has shattered the myth that there is a necessary linkage between economic growth and energy growth.

Between 1975 and 1983, the U.S. economy grew by 30 percent in real terms, while our energy use actually declined slightly. I believe that if you had had a witness at this table in 1973 predicting that outcome, he would probably have been laughed at.

But the point is that we have really only scratched the surface. There are certainly equal and probably far greater improvements still to be achieved. Many of them merely require the application of existing technologies. Some of them require vigorous research and development. Almost certainly, an R&D program will uncover new energy saving opportunities that we cannot now even guess at.

I have described in the written testimony in some detail what some of these opportunities are. If I could, in this short time, I will run through a couple of them.

We know that two-thirds of electricity use in this country is consumed by electric motors. Energy savings of 30 percent or more of this can be achieved through the application of new materials and control systems. Another quarter of U.S. electricity goes to lighting. Cuts of 50 percent or more are possible using existing new technologies, high frequency ballasts, isotopic enhancement, et cetera.

We need energy efficiency codes for buildings, just as we have them for wiring, plumbing and safety. If the private sector process that is now underway does not produce them, the Federal program that was repealed at the beginning of this Administration should be reinstated.

Similarly, Congress should repass the appliance efficiency standards the President vetoed after the close of the last session.

Huge improvements can be achieved in the transportation sector, which suffers, I think, from the worst case of technological inertia in this country. Prototype vehicles that use lightweight plastics, continuously variable transmissions and other innovations achieve 70 miles per gallon, with roomy interiors, high safety and high driving performance. These vehicles are being produced by European and Japanese companies, not American companies. Meanwhile, the Administration is seeking to weaken perhaps and, if it had its way, repeal our fuel efficiency standards.

The aggregate effect of these and similar efficiency policies is enormous. A global energy futures analysis supported by the World Resources Institute looked at developed, developing, and industrializing countries, and found that by applying the most efficient existing technologies in the context of optimistic projections of economic growth, you could look at a future in 2020 in which overall energy growth would only be slightly higher than it is at present, as compared to the conventional projections that involve a doubling or tripling of energy use.

On the fuel substitution side, photovoltaics, which produce, obviously, no CO_2 hold tremendous promise. Japan is spending 50 percent more on matching support for photovoltaic development than is the U.S. this year, and last year exceeded U.S. production by a substantial margin.

Meanwhile, the Administration has slashed Federal R&D spending on photovoltaics by a factor of four since 1981. The substantial technological lead that U.S. firms enjoyed in this field in the 1970s is disappearing, and is likely soon to be gone.

Similarly, as Gordon MacDonald mentioned, natural gas is considerably more carbon poor than is coal or oil. Its use in utilities in high efficiency gas turbines would give us tremendous efficiencies, but would require the repeal of the Power Plant and Industrial Fuel Use Act, which I believe would be possible in this Congress.

Federal leadership in this direction should also help redirect State regulatory policies that now preclude in many States the recovery of costs associated with trying new technologies.

In sum, there are a number of steps this Congress can take that will substantially lower U.S. energy demand without affecting economic growth.

The question then arises, do these steps together make a dent in the projected greenhouse warming? A computer model constructed by my colleague, Dr. Mintzer, shows that the date of a global commitment to the equivalent of a doubled CO_2 level could be delayed from 2030 to 2075 (which was as far as the model extended) through a set of policies not unlike these. That would buy us nearly five decades of very precious time—time to develop alternative energy sources and to take the adaptive steps that are going to be necessary.

This, of course, is not something that the U.S. can achieve alone. But our own energy consumption is so large—25 percent of the global total—and the power of our example still so great, that steps like these outlined here are necessary steps, and steps that will make a difference.

The next step is to begin international discussions, linking energy policy to greenhouse. A flourishing scientific exchange on this goes on now between the United States and the Soviet Union and could relatively easily be elevated to the political level. Considering that between them, these two nations account for 40 percent of global CO_2 emissions, this is an essential step.

The U.S. should also seek to engage China in discussions of that country's energy options. China currently sees few alternatives to a heavy reliance on coal, but the government has also shown itself to be very receptive to major policy shifts, if these will save money.

Senator MITCHELL. Could you sum up, Dr. Mathews?

Dr. MATHEWS. Yes. Let me turn for a minute to the last points that I wanted to make, linking this to these other issues.

We are heading, I believe, in the early to mid-1990s to another oil price shock and another energy crisis in the United States. The analysis for this is outlined in my written testimony. The point is that the date when the slack in today's market will be exhausted, depends completely on the rate of growth and energy demand in the interim.

If worldwide energy growth grows at three percent per year as it did in the U.S. in 1986, the slack will be gone in seven years or less. If it grows at one percent a year, the slack will not be gone for two decades.

So, we have the opportunity to delay the point at which OPEC will regain control of the international oil markets, if we choose to take it. And, again, the answer is, limiting energy demand.

Secondly, the implications for a U.S. economic competitiveness are equally great. The world is facing a transition period as we near the end of the oil era. That is inevitable. Energy prices and energy availability will be uncertain.

The challenge before us is to embrace the future and not to resist it. The active technological frontier is high energy efficiency. One has only to look at Japan to see the areas where we should be leading and are not. High efficiency automobiles, photovoltaic research—the list is very long.

In short, if the greenhouse effect did not exist at all, I would argue that a central thrust of Congress' initiative to restore U.S. economic competitiveness should be to recapture and extend our technological lead in high efficiency products, technologies, and processes, for those are what will own future economic markets.

I do not have time, I am sorry, to describe the links also between the third world debt crisis, but they are there. The energy efficiency strategy could constructively help long-term LDC economic growth which, considering that developing countries now account for 40 percent of our foreign markets, is also strongly in the U.S. economic interest.

Senator MITCHELL. I assure you your full statement will be in the record. Thank you very much.

Mr. Barnett.

STATEMENT OF RICHARD BARNETT, CHAIRMAN, ALLIANCE FOR RESPONSIBLE CFC POLICY

Mr. BARNETT. Thank you, Mr. Chairman.

In the interest of time, I am going to deviate from the written statement. I would just like to leave you with a few thoughts with regard to CFCs.

I am here representing the Alliance for Responsible—I would like to emphasize "Responsible"—CFC Policy within the United States. This Alliance is a coalition of about 500 businesses in the United States, both users and producers of CFCs.

I might remind you that CFCs are utilized in air conditioning and refrigeration, both automobile air conditioning and home and commercial air conditioning. They are also utilized in making foam plastics for insulation as well as for containers, and for food processing and for chemical cleaning.

I might remind you also that the characteristics of CFCs are unique. They are non-carcinogenic. They are non-toxic. They are non-flammable. They are non-corrosive. And they are very energy efficient in the applications that they perform.

This doesn't say, however, that the industry disagrees with some of the things that have been said earlier today. In a recent policy statement, which all of you have been made aware of, the industry

has come out with a policy which concludes that the negotiation of an international agreement under the auspices of the United Nations Environmental Programme on global production capacity for the fully halogenated CFCs is necessary.

The development of voluntary CFC conservation programs by the user industries is also highly desirable and necessary in order to make sure that we use them wisely.

We urge the continuation of development of scientific understanding with regard to the ozone depletion theories, and the implications on CFCs, and the research and development by producers and users of alternative CFCs, for products and processes to reduce reliance on the more offensive formulations of these compounds. Actually, there are some of these compounds that are part of the solution and not part of the problem.

It is our belief that the Alliance for Responsible CFC Policy, working in conjunction with the environmental groups, the State Department, and EPA, we can form a very formidable alliance together to impact the world. We, the United States, cannot solve this problem on our own. We are about one-third of the total world's production, and we need worldwide agreement.

An aggressive approach, as identified by Mr. Negroponte, I think, is right in line with what is needed in order to respond to the current situation.

The other thought I would like to leave you with is that this is a problem that must be managed. The current production of CFCs is anticipated according to the NASA study to be tolerable by the ecology. Its increases in production rates are intolerable, and the industry endorses a limiting of future growth of production of CFC compounds. Conservation can also utilize these CFC formulations more productively. We also urge the substitutions to more stable compounds of CFCs and new formulations.

But we urge you to consider that we could be potentially inducing bigger problems than what we are solving if we don't be careful with the new compounds we are introducing, both from a toxic standpoint and from a worker and consumer safety standpoint.

If those of you who do not believe that propane in aerosols is dangerous, simply take a cigarette lighter and exhaust the aerosol through it and you have a very nice flame thrower.

Senator MITCHELL. Thank you, Mr. Barnett.

Mr. Doniger.

STATEMENT OF DAVID D. DONIGER, SENIOR ATTORNEY, NATURAL RESOURCES DEFENSE COUNCIL

Mr. DONIGER. Thank you.

I would like to talk about chlorofluorocarbons and certain related chemicals that affect the ozone layer—halons, which are bromine-containing chemicals, and certain chlorinated solvents which also last long enough to find their way up there.

On behalf of Natural Resources Defense Council, I have been involved for the last three years in the domestic and the international activities on those chemicals. I have been to the Geneva UNEP negotiations. I will be in Vienna for the next session. I have had a close opportunity to view what is going on domestically and inter-

nationally. And let me offer some reactions and suggestions. I am reflecting the views of Natural Resources Defense Council and other environmental groups in the U.S., and I might add also in Europe, too.

Attached to my statement is a joint statement of European and American environmental organizations signatories, more than in the U.S., in fact. The statement calls for a worldwide global phase-out of the CFCs, halons, and related compounds and the replacement of them with safe substitutes. It also calls for the minimization of emissions by maximizing technologies for recovering, recycling and destroying the quantities of these chemicals that remain in use.

We propose a specific schedule for the phase-out: a 30 percent reduction over 18 months; an 85 percent reduction over five years; and an essentially complete phase-out over ten years.

I would emphasize that this kind of a schedule is proposed on the assumption that the ozone hole is not caused by CFCs, and that certain NASA satellite data, which detects higher rates of depletion than models project, is not connected to CFCs. If the research should show that there is a significant probability that these phenomena are linked to the chlorine or the bromine from these substances, then we will be facing a global emergency. In that case the phase-out would have to occur immediately.

There has been a major change over the last year in the U.S. industry's approach to this problem, from an almost fanatical opposition to regulation to a more moderate view that admits there is a serious problem. The producers, especially Dupont, are more optimistic than they used to be about their ability to make substitutes. They will likely be more expensive, at least in the short run, and one area of agreement between industry and environmentalists is a recognition that government incentives, such as those provided by a phase-out, are needed to make the substitutes economically viable.

You have heard the State Department and EPA positions described, and I would like to address how they measure up against the need.

I was prepared to say more positive things in my written testimony about the U.S. position than I think I have to now, given what I just heard from Mr. Negroponte. One of the big questions in all your minds and in our mind is how long, in the view of the State Department and EPA, is a "long-term phase-out." Mr. Negroponte answered Senator Baucus' question by suggesting that it might be as long as 20 years.

That is a major change from what I understood the U.S. position to be as late as December, when privately we were being told that the period the delegation was authorized to negotiate was something on the order of eight to twelve, or maybe fourteen years. Now, it is an odd policy to have your strong position as your secret one and your weak position as your public one.

I really hope the Committee will follow up and seek to get that statement by Mr. Negroponte corrected. And if it is in fact their position that a phase-out should be allowed 20 years, then that is the reason why we are going to need domestic legislation and not leave things to the Administration.

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I would like to talk for a minute, if I might, about what we ought to do domestically. I disagree with the view that unilateral action should be postponed until an international agreement is reached, or should not be taken if such an agreement cannot be brought about. The U.S. makes a large contribution to the world's CFC use. We have a responsibility to deal with that, and to lead.

But there are also means at our disposal, as Senator Chafee and others have mentioned, to leverage cooperation by other countries; to protect our domestic industries; and also to enhance the competitive position of U.S. industry all at once. The way to do this is to couple a domestic phase-out with an import restriction that would prevent finished products that were made with CFC's and related compounds, or that contain these compounds from coming into the United States, unless the country where they come from is on a parallel phase-out course.

The U.S. Trade Representative recently issued a legal opinion saying we are permitted to do this, under the General Agreement on Tariffs and Trade, because it has a clear health and environmental justification and treats foreign and domestic products in the same way.

I can't overemphasize how a phase-out would enhance U.S. competitiveness. The incentives created by a reduced supply of conventional CFCs would give U.S. industries the opportunity to steal a march on foreign competitors in the race to commercialize substitutes and recycling techniques, et cetera. Nearly all informed persons would bet that there will be continued adverse scientific findings that will compel Europe, Japan, and other countries to follow our lead, if not right away, then in a little bit. If the U.S. acts first, our companies will be poised to export, not to import, the technologies of the future.

But here on the domestic side as well as the international, we are very uncertain where EPA is headed. All options, ranging from the good ones sketched out here to completely unacceptable inaction, appear to be under analysis. Guided by experience, EPA is behaving as though it expects the Office of Management and Budget to be a major hurdle.

Consequently, it is critical that Congress pass legislation which imposes a domestic phase-out and couples it with the restriction on imports from non-cooperating countries.

A good outcome from the U.S. regulatory process, or from the State Department's position in the negotiations, is a slender reed to count on at this point. The U.S. should be proposing a domestic phase-out, and to do that would strengthen the hand in the international negotiations, because other countries would see that if they don't negotiate a deal with us, they are going to not be able to bring their cars and their computers and other products into our country.

If the negotiations still fail, they would have to follow suit, based on the fact that those markets are much more important to them than making an adjustment in how they use CFCs.

So I would strongly recommend that this Committee and the whole Congress enact such a policy into law at the soonest possible time.

Thank you.

Senator MITCHELL. Thank you, Mr. Doniger. Thank you all. I will ask just a couple of questions and then go to my colleagues.

Mr. Doniger just expressed the view that if international efforts fail, the U.S. should seek unilateral reductions. Could I ask each of you briefly whether you agree with him or disagree with him. Mr. Barnett, your answer?

Mr. BARNETT. As I understand your question——

Senator MITCHELL. Mr. Doniger expressed a view contrary to one previously expressed by other witnesses, that if international efforts fail the United States should seek unilateral reductions in emissions of CFCs. My question is, do you agree with Mr. Doniger?

Mr. BARNETT. I don't think we should necessarily look at reductions. I think we should look at a cap of CFC rate of increase or production of CFCs as warranted by the scientific findings. I don't think, however, that the international arena is going to fail.

I think that there is a high degree of confidence, not only in the State Department but also in my own personal interfaces with several international representatives that indicate that there seems to be a consensus of opinion formulating around what Mr. Negroponte identified, and I think there is a high degree of confidence we will get an agreement through the UNEP meetings.

Senator MITCHELL. Well, we hope so. My question is really based on the assumption that if it didn't.

Dr. Mathews, do you agree or disagree with Mr. Doniger?

Dr. MATHEWS. I would agree with him. But, again, I think it is a false choice right now. We are entering an era in which these global issues are going to be more and more before us. And we have to establish the precedent and begin to establish success at achieving global agreements. And this one, I think, has high prospects for success and I would urge Congress to put its attention and effort in trying to get it to succeed.

I think there are a great many things that you can do—close oversight, tough oversight, such as we have seen this morning; and continuing pressure on the schedule of the negotiations, on UNEP, which I think would be eager to listen; pushing the State Department to raise this issue at the Ambassadorial level in a great many other capitals than they have yet and basically raising this issue to the political agenda in every respect; and Congress itself raising it with European legislators and European heads of state and ministers with whom you meet regularly.

That will do a great deal to raise the level of urgency and the prospects for success of these negotiations.

Senator MITCHELL. Thank you.

Dr. MacDonald?

Dr. MACDONALD. I agree with Dr. Mathews. I view these negotiations as a possible model for future negotiations involving very complex and difficult environmental issues. This, I feel, is much simpler than some of those that we are going to have to face in the future.

So I would strongly urge that all steps be taken to try to achieve a success in these negotiations.

Senator MITCHELL. One more question I will ask each of you.

Mr. DONIGER. Senator, excuse me. But I have one comment.

Senator MITCHELL. Go ahead.

Mr. DONIGER. I think it is important to recognize the connection between the domestic and the international negotiations in a way that has not been put before, which I was trying to suggest.

Senator MITCHELL. Well, you did that very clearly in your statement, Mr. Doniger.

Mr. DONIGER. What we get out of the negotiations will depend on what we are telling other countries we will do to them if we don't get a good agreement. And that is the reason why we should be considering very strongly, and I believe enacting, this proposal now. It could even have a self-destruct provision in it if there is an adequate international agreement.

I want the negotiations to succeed, too. But it should be very clear to Japan and the EC what would happen if the negotiations fail.

Senator MITCHELL. One of the problems that we face continuously is the balancing between making public policy decisions with less than complete information. We are constantly urged to wait until there is more research on the one hand, and on the other hand we are urged to act before damage or adverse effects become irreversible or larger than justified.

Does anybody on this panel disagree that we now know enough about this issue to justify controlling the emissions of greenhouse gases and other air pollutants?

Mr. BARNETT. Controlling on a worldwide basis? Yes, we agree. I would agree.

Senator MITCHELL. What about here in this country? You have already said that you would favor a freeze.

Mr. BARNETT. No. On a worldwide basis, we would favor a freeze on the growth of CFC production.

Senator MITCHELL. Only on a worldwide basis?

Mr. BARNETT. We believe that the United States alone cannot solve the problem and, in fact, unilateral action by the United States could, in fact, inhibit a worldwide agreement rather than enhance it. And I will refer to the aerosol ban which was not followed by anyone except for a couple of Nordic countries.

Senator MITCHELL. Yes.

Mr. BARNETT. And I don't think that that is really the mark of leadership. I think the mark of leadership is leading the world to the altar, if you will, of a unified, fair type of a cap to solve the problem, rather than to solve the symptom.

Senator MITCHELL. Do any of the remaining three disagree with the conclusion that we know enough to now regulate the emissions of greenhouse gases? Mr. Doniger?

Mr. DONIGER. I completely agree with you.

Senator MITCHELL. Dr. Mathews?

Dr. MATHEWS. I agree.

Senator MITCHELL. Dr. MacDonald?

Dr. MACDONALD. I certainly agree.

Senator MITCHELL. Thank you very much. I yield now to Senator Chafee.

Senator CHAFEE. Thank you. I won't be long.

Mr. Barnett, I looked at your statement carefully. On page 2 the key elements of your policy, you say, and I assume that you were consciously using the words "global production capacity." Now, ca-

pacity is a lot different from production. In other words, you are even further to the right of the European community. Most of these people have agreed to work on production.

In other words, how much did you produce in 1985 or 1986, use that as a base; not how much could you have produced, which is capacity.

Am I correct that you were cognizant of what capacity meant?

Mr. BARNETT. We purposely put that in there when we drafted the policy, giving a broad enough latitude to the State Department to negotiate what we thought would be able to be achieved within the European economic community in order to be supportive of that.

The industry would be most supportive of putting some limit on production, not capability but production level.

Senator CHAFEE. But you went further out. You went to capability? That is what capacity means.

Mr. BARNETT. The way that the statement is written, yes. But the industry would be agreeable to putting a production limitation at less than the full capability of production worldwide.

Senator CHAFEE. That is encouraging. Now, let me ask you this. Representing the companies that you do, we had testimony last summer that substitutes could be devised of CFCs in the mobile air conditioning units, automobile air conditioning units, that were the nondestructive type of CFCs. However, it would take some changes in the piping involved in the mobile units. But the cost increase would be modest. Do you agree with that?

Mr. BARNETT. Well, I don't think the issue is with the system itself. I think the issue is with the chemical, the substitute CFC chemical. To the best of my knowledge, there has been no proven production capability for the formulation 134a that people talk about. And the yield of toxic waste as a percent to the total input of chemicals is right now pretty high.

So, what we need is a production capability of the chemical and then once that is achieved, we can look at what minor refinements need to take place in the actual air conditioning system itself.

Senator CHAFEE. OK. I am asking you to truncate your answers if you can. Quickly, the companies that you represent, do they have the capacity or are they working on producing substitutes for the CFCs that are now in refrigeration units and air conditioning units?

Mr. BARNETT. Yes.

Senator CHAFEE. And do you think that they could produce that at a price that is not exhorbitant?

Mr. BARNETT. I am really not qualified to answer that, but I believe that the price premium for the substitute material would probably be able to be afforded. That is an opinion, not a fact.

Senator CHAFEE. And finally, Mr. Doniger, I support your suggestion about prohibiting the import of those products that were based on CFCs, but is there any way of ascertaining whether a Japanese chip was washed or cleaned with CFCs? Is that beyond our realm?

Mr. DONIGER. As I understand it, there are some products, and that is one, where it is technically difficult to verify it. But there are certification systems which you can use, too, where you make it

a criminal penalty for someone to lie about the background of these products.

Senator CHAFEE. Well, it is awfully hard for us to impose a criminal penalty on a Japanese——

Mr. DONIGER. Excuse me, on the importer. And there are fraud provisions in the Customs laws right now that make it a crime to lie about important characteristics of an import.

Senator CHAFEE. Thank you very much.

Mr. Chairman, I hope that some time we will get an opportunity—and I suppose this is going to be a continuing thing—I would be interested in the production capacity of U.S. companies, whether they can produce the substitutes. Much of our discussions here has been about becoming competitive in this field. I hope sometime we can hear perhaps from DuPont or Allied, or whoever it might be. Thank you.

Senator MITCHELL. Senator Baucus.

Senator BAUCUS. Thank you, Mr. Chairman.

Mr. Barnett, on that very question, very briefly, isn't this a good opportunity for American industry to gain a competitive advantage? In other words, find the substitutes? It is clear where the world is going, why not take advantage of the opportunity?

Mr. BARNETT. I think that may be one of the reasons why we don't know whether—why we all don't know the exact status of substitute formulations. It becomes a competitive arena for all manufacturers involved. And some of this data, the manufacturers are obviously reluctant to share exactly what their status is.

But I am convinced there is a lot of work going on behind the scenes to position companies for a competitive advantage.

Senator BAUCUS. Thank you very much. Thank you, Mr. Chairman.

Senator MITCHELL. Thank you, Senator Baucus. You set a commendable example of brevity.

Senator Gore?

Senator GORE. Thank you, Mr. Chairman. I will not ask any questions. I will rather make a very brief statement.

Senator MITCHELL. For the record.

Senator GORE. For the record.

Mr. Barnett, I just want to say that there are companies in Tennessee that are part of your coalition. I have heard from them. I have been in communication with some of their employees. And I know that Congressmen and Senators from around the country will also be in communication with them.

I respect the fact that your coalition has modified its position. In some ways, it is an uncharacteristic adjustment for an industry group to go as far as you have. And I so sympathize with the fact that you are being beat upon to do even more, but I honestly think you have got to do a lot more.

I do respect what you have done. But I must identify myself with the proposal that Senator Chafee mentioned earlier, the idea of unilateral action with trade restraints, justified on health and environmental reasons. I just think the risk is too great, and I think we must do a great deal more.

And, finally, I would like to just express serious reservations for the record about your characterization of the NASA study indicat-

ing the environment can absorb the present level of CFC, because I think it does not.

Your statement does not take into account the different stratospheric levels of CFC concentrations and, in fact, what the graph you pointed to cites is that there would be continuing ozone depletion in the levels of the atmosphere where it is needed, and the compensating increases would be in the form of smog. So, I don't think that is the outcome that we want.

I will leave it at that, Mr. Chairman, and thank you again for your graciousness and courtesy.

Senator MITCHELL. Mr. Barnett, you would have been better off if he had asked a question.

Senator GORE. If you want to give him a chance to respond, that is fine.

Senator MITCHELL. In that regard, the record will remain open for one week to permit further questions to be submitted by members of the Committee in writing to the witnesses. If you receive any questions in writing, we hope that you will respond as promptly as you can.

On behalf of the members of the Committee, I thank all of the witnesses for their courtesy.

And last, but not least, you are the only panel that we had a technician here making sure that your words were recorded. The others, I hope we have got them, but we are not sure. In any event, it has been a very instructive and informative hearing. I thank everyone for their contribution.

The hearing is concluded.

[Whereupon, at 12:52 the hearing was adjourned.]

[Statements and responses to additional questions follow:]

Testimony

by

Wallace S. Broecker
Professor of Geochemistry

Lamont-Doherty Geological Observatory
of Columbia University

before

The United States Senate
Subcommittee on Environmental Protection
Chaired by George J. Mitchell
January 28, 1987

Revised
January 24, 1987

GREENHOUSE SURPRISES

LESSONS FROM THE PAST:

The inhabitants of planet Earth are quietly conducting a gigantic environmental experiment. So vast and so sweeping will be its impacts that, were it brought before any responsible council for approval, it would be firmly rejected as having potentially dangerous consequences. Yet the experiment goes on with no significant interference from any jurisdiction or nation. The experiment in question is the release of CO_2 and other so-called greehouse gases to the atmosphere. As these releases are largely byproducts of energy and food production, we have little choice but to let the experiment continue. We can perhaps slow its pace by eliminating frivolous production and by making more efficient our use of fossil fuel energy. However, beyond this we can only prepare ourselves to cope with the impacts the greenhouse buildup will bring.

As scientists, our task is to predict the consequences of this buildup. To be useful these predictions must be reasonably detailed. It is my feeling that we are in no better a position to make these predictions than are medical scientists when asked when and where cancer will strike a specific person. Understanding the operation of the joint hydrosphere, atmosphere, biosphere, cryosphere...system is every bit as difficult as understanding the factors which determine whether or not cancerous cells will get the upper hand. Because of our lack of basic knowledge, the range of possibility for the greenhouse impacts remains large. It is for this reason that the experiment is a dangerous one. We play Russian roulette with climate hoping that an impact scenario of minimum consequence

lies in the active chamber. While I don't claim to know what lies in the chamber, I am less optimistic about its contents than many. I suspect we have been lulled into complacency by model similations which suggest a gradual warming over a period of 100 or so years. If this seemingly logical response to a gradual greenhouse buildup is correct, then one can imagine that man, aided by his ingenuity and technology, will be able to cope with the coming changes. While I do not have any complaints about how these modeling experiments were conducted - indeed they were done by brilliant scientists using state-of-the-art computer power -, I am convinced that the basic architecture of these models denies the possibility for key interactions which occur in the real system. The reason is that at present no meaningful way exists to incorporate these interactions into models.

My impressions are more than educated hunches. They come from viewing the results of experiments nature has conducted on her own. The results of the most recent of these experiments are well portrayed in polar ice, in ocean sediment, and in bog mucks. What these records tell me is that Earth climate does not respond in a smooth and gradual way, rather it responds in sharp jumps. These jumps appear to involve large scale reorganizations of Earth system. If this reading of the natural record is correct, then we must consider the possibility that the major responses of the system to our greenhouse provocation will come in jumps whose timing and magnitude are unpredictable. Coping with this type of change is clearly a far more serious matter than coping with a gradual warming.

While I cannot in this brief testimony provide a complete case in defense of my hypothesis, I can give enough of a glimpse at the evidence to capture your attention.

For over 100 years scientists have been aware that the Earth is in the midst of a series of cyclic glaciations. During each of these glaciations, ice caps covered much of North America and Europe to a depth of 2 or so miles. Average global temperatures were down about 5°C. Sea level dropped over 100 meters. The CO_2 content of the atmosphere was about two thirds its value during the warm intervals separating these icy episodes. The radiocarbon dating method tells us that the planet emerged from the most recent of these glaciations about 10,000 years ago. Mankind responded to this ease of conditions by rapidly developing a civilization. Early agriculture, for example, goes back 9000 years.

Deep sea sediments provide continuous records of these events showing that cycles averaging 100,000 years in length carried us from warm climates, comparable to today's, to the cold climates of full glacial time. The timing of these changes points a finger at cycles in the Earth's orbital characteristics as the cause for the repetitive swings. These cycles in orbital character cause the winter to summer contrast in the amount of sunlight reaching any given place on the Earth to change. Seasonality was at times stronger and at times weaker than today's. While most scientists now accept the orbital hypothesis, none of the mechanisms which have been proposed to explain the linkage between seasonality and climate has received broad acceptance. This matter is the subject of considerable current research and debate.

Because the deep sea sediments we study are stirred by worms (just as the soils in our gardens) they leave the impression of smooth and gradual climate change (see Figure 1). Only recently have scientists begun to realize that this impression is a false one. Rather, at least in some regions of the Earth (in particular the one inhabited by our NATO allies) the climate changes were abrupt. One of the early clues came from studies of the shells of microscopic organisms contained in deep sea cores of high accumulation rate obtained in the northern Atlantic. Rather than showing the gradual change scientists had become accustomed to, they showed an abrupt end to glacial time and even more interesting a brief period of intense cold interrupting the warm period which followed (see Figure 1).

It took more than this, however, to make scientists think seriously about the consequences of these abrupt changes. The evidence which turned our heads came from borings made through the Greenland ice cap. As no worms live in the ice and as a foot or so of ice forms from each year's snowfall, the record accurately captures the changes in the ice cap environment. These changes are recorded in the ratio of isotopically "heavy" to isotopically "light" water in the ice (a measure of air temperature), in the content of particulate matter in the ice (a measure of the dustiness of the air over the ice cap) and in the content of CO_2 and other greenhouse gases contained in the air trapped as bubbles in the ice (a measure of the atmosphere's greenhouse capacity). Like the ecologic record in deep sea muds from the northern Atlantic, the ice core records from Greenland give a dramatically different impression of the manner in which climate changes.

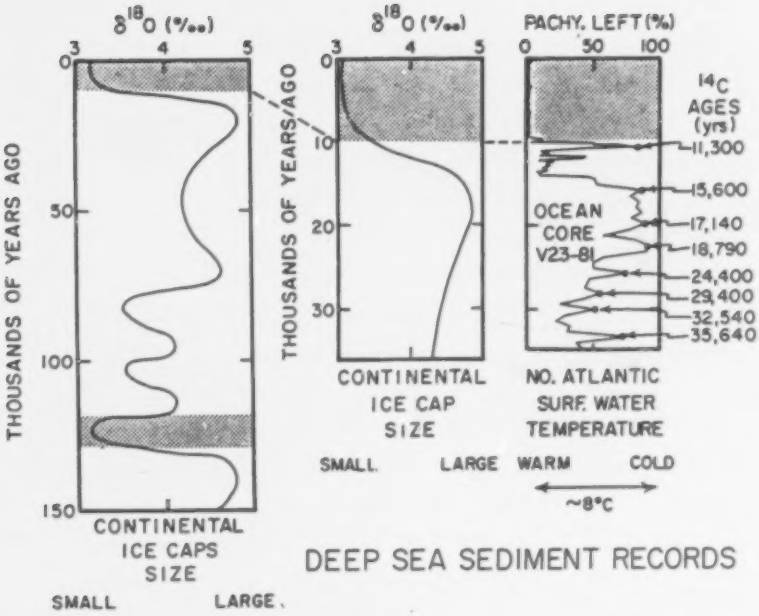

Fig. 1 The ratio of heavy oxygen (^{18}O) to light oxygen (^{16}O) in the foraminifera shells preserved in deep sea sediments provides our best record as to how the great continental ice sheets of the northern hemisphere waxed and waned. The reason is that the snow that builds ice caps is depleted in the heavy oxygen isotope. Hence, as ice caps grow, the ocean is correspondingly enriched in heavy oxygen. So also is the oxygen in the $CaCO_3$ of shells grown in these waters. The oxygen isotope record on the left covers just over one major climate cycle. There have been 8 such cycles in the last million years. The shaded intervals are periods of interglaciation. The diagram in the middle is a blow up of that on the left designed to emphasize that these oxygen isotope records suggest a gradual and smooth transition from full glacial conditions about 16,000 years ago to full integlacial conditions about 8000 years ago. Recent findings demonstrate that this view of natural climate change is misleading. The sluggish retreat of the ice and blurring of the record by burrowing worms combine to give what proves to be the wrong impression.

At the right is the record from a deep sea sediment obtained west of the British Isles. Here the blurring by burrowers is minimal. Also, the record is based on the abundance of the shells of a planktonic herbivore named Pachyderma (left coiling) which now lives in waters adjacent to Greenland. It is the only species found in these icy waters. During cold periods this species dominated the entire northern Atlantic, providing up to 90% of the shells found in the sediments off England. As can be seen, this record tells a different story. The northern Atlantic Ocean warmed abruptly about 15,000 years ago, and has so remained (except for two brief cold relapses) until the present. It is the abruptness to the warming and of the two brief and intense epochs of renewed cold which are of great interest. The second of these cold epochs was first recognized by scientists studying the pollen records from bogs created in northern Europe during the retreat of the last great ice sheet. These records show that the forests which repopulated this area after ice departed were destroyed by a brief and intensly cold interval of several hundred years duration. They were replaced by the shrubs of glacial time. This awesome cold event is referred to by palynologists as the Younger Dryas.

The ice records show climate changing frequently and in great leaps. The typical leap involves a 6 degree centigrade change in air temperature, a fivefold change in atmospheric dust content and a 20% change in the CO_2 content of air. In cold times the air was dustier and had less CO_2 (see Figure 2). While the record in Greenland's ice tells us that climate can change in big leaps, we have to look further for a clue as to why these leaps occur. The last of the events seen in the Greenland record (called the Younger Dryas) is well documented not only in Greenland ice and in north Atlantic sediment, but also in lake and bog sediments from throughout western Europe and maritime Canada. It is recorded by major shifts in the ecology of the plants inhabiting the regions around these water bodies (recorded by their pollen grains). During warm periods trees grew in these areas; during cold periods the trees were replaced by tundra shrubs.

The clue we needed comes from the geographic distribution of the Younger Dryas event provided by this pollen evidence. While the event is found in bog and lake sediments throughout northern Europe, it is not seen in similar records from the United States. Rather, its impacts are confined to the northern Atlantic Ocean and its surrounding land masses (see map in Figure 3). This geographic distribution points at the northern Atlantic Ocean as the casual culprit. Based on this clue, scientists are beginning to see how devilish are the links between components of the climate system.

To understand this, we must delve into the ocean's role in climate. Those of us who live in coastal cities know that heat stored in off shore waters during the summer is released during the winter greatly ameliorating the intensity of seasonal change (compared to that experienced by the of the continental interior). Less well known is the fact that western Europe is warmed by heat released from the surface waters of the northern

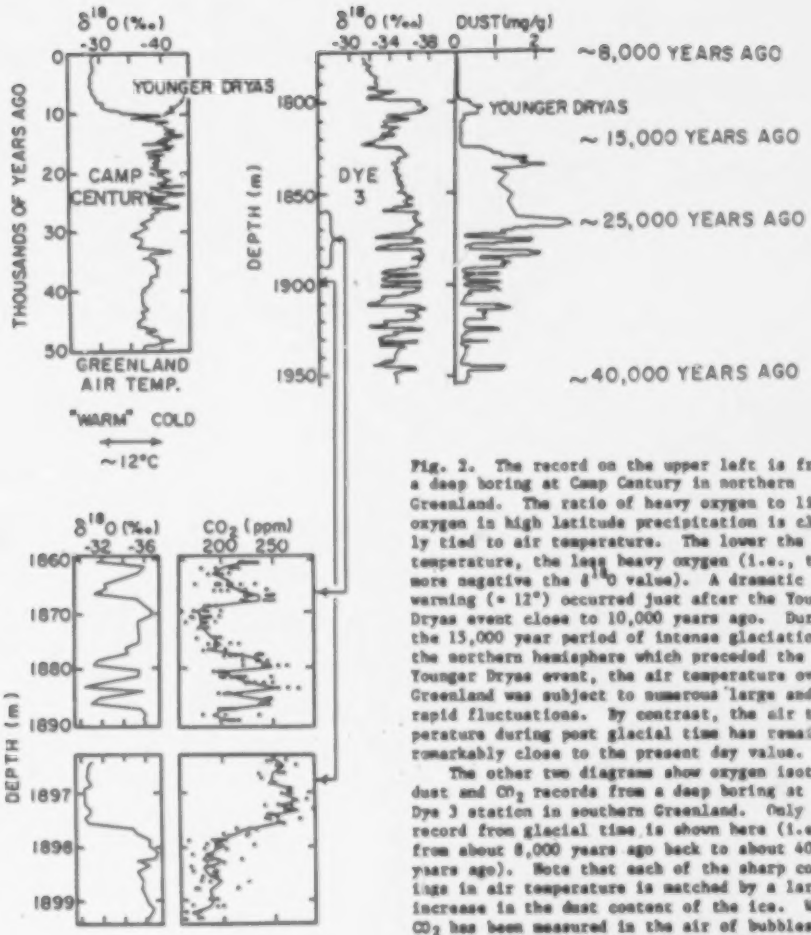

Fig. 2. The record on the upper left is from a deep boring at Camp Century in northern Greenland. The ratio of heavy oxygen to light oxygen in high latitude precipitation is closely tied to air temperature. The lower the air temperature, the less heavy oxygen (i.e., the more negative the $\delta^{18}O$ value). A dramatic warming (≈ 12°) occurred just after the Younger Dryas event close to 10,000 years ago. During the 15,000 year period of intense glaciation of the northern hemisphere which preceded the Younger Dryas event, the air temperature over Greenland was subject to numerous large and rapid fluctuations. By contrast, the air temperature during post glacial time has remained remarkably close to the present day value.

The other two diagrams show oxygen isotope, dust and CO_2 records from a deep boring at the Dye 3 station in southern Greenland. Only the record from glacial time is shown here (i.e., from about 8,000 years ago back to about 40,000 years ago). Note that each of the sharp coolings in air temperature is matched by a large increase in the dust content of the ice. Where CO_2 has been measured in the air of bubbles trapped in the ice, these sharp coolings are matched by sudden drops in CO_2 content. The oxygen isotope and dust records were obtained by Dansgaard and his group in Copenhagen, Denmark. The CO_2 records were obtained by Oeschger and his group in Bern, Switzerland. The Greenland ice cores were obtained by a team made up of Americans, Danes and Swiss.

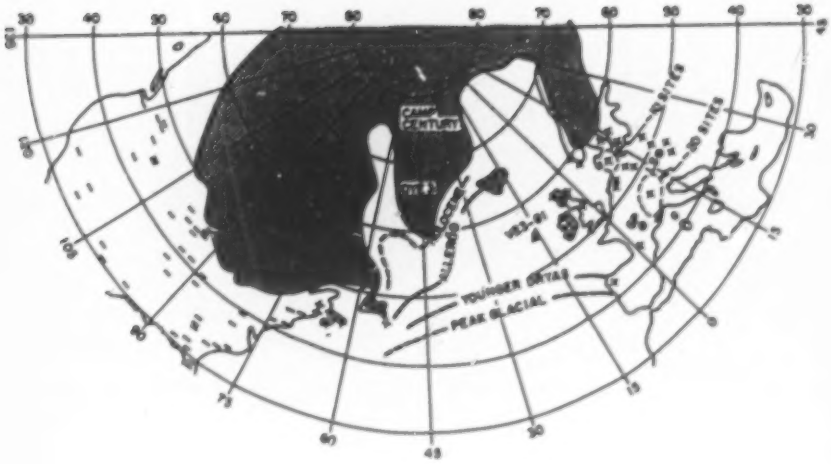

Fig. 3. This map shows sites where the Younger Dryas is found in pollen records (+s) and sites where it is not found (-s). As can be seen, it is confined to northern Europe and maritime Canada. No trace is found in U.S. sites. The combined evidence suggests that the northern Atlantic was a cold icy ocean during glacial time and during the brief Younger Dryas event which punctuated the warm period which followed glacial time. During the warm interval which preceded the Younger Dryas event (called the Allerod) and during the warm interval which followed the Younger Dryas the northern Atlantic waters were moderate in temperature.

Atlantic. In this case the amount of heat released is so great that it cannot be accounted for by storage during the summer months. It amounts to a staggering 30% of that received by the northern Atlantic from the sun! Rather, this heat is steadily carried northward by a conveyor belt like ocean circulation system (see Figure 4). This conveyor belt carries more than 10 times the combined flow of the world's rivers! This water moves northward into the region around Iceland. Here it gives up the heat it gained at lower latitudes to the winter winds blown in from northern Canada. The cooling makes the water more dense causing it to sink to the abyss. From here it flows through the deep sea as a great river, down the full length of the Atlantic, around Africa through the southern Indian Ocean and finally up the Pacific Ocean (see Figure 4).

It is important to note that in the north Pacific the ocean conveyor belt runs just the other way round from that in the Atlantic. Deep waters move toward the north and upwell to the surface and then move equatorward in the upper ocean. So in today's world the Atlantic Ocean conveyor belt carries tropical heat for delivery to the atmosphere at high northern latitudes, while the Pacific conveyor belt is forces cold surface waters to move southward, pushing the invading warm waters back toward the equator.

Why does our ocean operate in this fashion? While we don't have the complete answer, we do have the first principles. The circulation system is governed by salt. Because of the difference in the circulation patterns, surface waters in the North Atlantic are on the average warmer than those in the North Pacific. This allows more water to evaporate from the North Atlantic than from the North Pacific and in turn gives rise to a net transport of water vapor through the atmosphere from the Atlantic to the Pacific. As the ocean's salt can't evaporate, the North Atlantic is

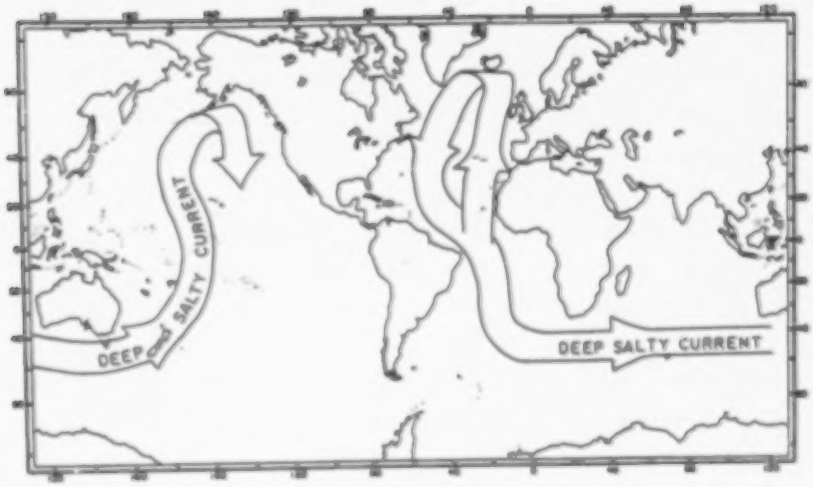

Fig. 4 A large scale salt transport system operates in today's ocean as a counter balance to the transport of water (as vapor) through the atmosphere from the Atlantic to the Pacific Ocean. Upper waters in the North Atlantic flow northward to the region around Iceland. Here they give up heat to the atmosphere and descend to the abyss as new deep water. This deep water flows down the length of the Atlantic around Africa through the southern Indian Ocean and finally northward in the deep Pacific Ocean. Some salty water upwells in the northern Pacific bringing with it the salt left behind. This atmospheric water vapor and ocean salt transport system is self stabilizing. Records from ice and sediment tell us that this great conveyor system was somehow disrupted during glacial time and replaced by an alternate mode of operation.

enriched in salt by this process (and the North Pacific waters correspondingly diluted). The enrichment of salt in the North Atlantic must somehow be compensated by a flow of salt through the sea from Atlantic to Pacific. The compensation in today's ocean is achieved by the flow of a deep current of salty water from the Atlantic to the Pacific and a matching flow of corresponding less salty water around the other way in the upper ocean.

The phenomena which maintains this situation is a devilish one and I suspect a potentially dangerous one. The circulation pattern is self reinforcing and hence self stablizing. The deep current is driven by the extra density supplied to the northern Atlantic by the enrichment of salt. The enrichment of salt is driven by the heat carried by the warm water which flows northward in the Atlantic to supply the deep current. A classic chicken and egg situation! Excess evaporation causes the deep current; the deep current causes excess evaporation.

Now back to the sharp events. The evidence we have points to a shut down of the North Atlantic conveyor belt circulation during glacial time. Such a shut down would cool the northern Atlantic and its adjacent lands by 6 to 10°C. This in turn would cause the boreal forests in these areas to give way to tundra shrubs. The sparcity of vegitation would permit far more dust to be lifted into the atmosphere. Finally, the only feasible mechanisms scientists have come up with to explain rapid changes in the atmosphere's CO_2 content recorded in ice cores involve modifications in ocean's circulation pattern and intensity. Thus we surmise that the reorganization of ocean circulation which accompanied the shut down of deep water production in the northern Atlantic also produced the change in the CO_2 content of the Earth's atmosphere recorded in ice cores. The many leaps in climate seen in the glacial part of the Greenland records very

likely represent flips of the system back and forth between two self-stablizing modes of operation.

The important point of all this is that the great leaps in the climate of the northern Atlantic region have opened our eyes to an entire new realm of climate interactions. No one will deny that the pattern and rate of global scale ocean currents is strongly tied to the alterations in salt distribution caused by the transport of water vapor through the atmosphere from one ocean basin to another. No one will deny that the temperature of high latitude land masses is strongly influenced by heat transported by currents in the adjacent ocean. No one will deny that the content of CO_2 in the atmosphere depends on a linkage between ocean circulation and ocean life cycles. Further, most would agree that the present mode of operation is not God given. The climatic records kept in ice and sediment speak strongly to us that past climate changes have involved such reorganizations. If so, why not the future climate changes as well? The increase in the atmosphere's burden of greenhouse gases may force a reorganization of the Earth system into yet another mode.

At this point it must be emphasized that the leaps in climate seen in the ice and sediment records for the northern Atlantic region were confined to the cold parts of the climate cycle. Following the transition from cold to warm conditions 10,000 years ago, the climate in this region has remained remarkably constant. Apparently the Earth system has been firmly locked in its present mode of operation for this entire period. If so, what is the likelihood that increases in CO_2 and other greenhouse gases will be able to jolt the ocean-atmosphere system out of its current mode into one more suitable to the coming conditions?

Unfortunately, we have little basis for answering this important question. Nature provides us with no recent analogue of the superinterglacial conditions we are about to generate. The climate of the last

10,000 years is representative of the warmest part of the last several glacial cycles (see Figure 1). Hence nature has not explored the super-interglacial climate regime (at least not in sufficiently recent times that our geologic records give a rich enough picture of Earth environment to be useful for future prediction). Further, as we have only recently become aware of complexity of the linkages which tie together the ocean, atmosphere, ice, and terrestrial vegitation, we have not even begun to formulate means by which these linkages might be modeled. Indeed, reliable prediction may never be possible. If this is the case, then our grand experiment could certainly prove to be a dangerous one!

PROPOSED ACTION:

What should we do? Clearly burying our heads in the sand as we have been prone to do is irresponsible. Wringing our hands in anguish over our inability to stop the potentially dangerous experiment accomplishes nothing. There are two things we can do. First, we must explore every economically and environmentally feasible means to hold down production of greenhouse gases. Second, we must greatly expand our efforts to better understand the operation of the Earth's complex environment system.

As my expertise applies only to the second of these needed actions, I will confine my remarks to it. First of all if we are to get ourselves in a position to understand the impact not only of the greenhouse gases, but also of the acids and the poisons being released to the environment we must greatly expand our effort to understand individual units of the great Earth surface system and the interactions among these units. Over the next decade or so, we must ramp up our efforts by tenfold. The task is every bit as complex as the crusade to prevent cancer and the crusade to defend against nuclear missiles.

Also needed is a complete reorganization of our country's approach to environmental research. I believe that most scientists would agree with me that the handling of research on greenhouse gases by DOE and on acid rain by EPA has been a disaster. Not only do these agencies misspend much of the money allocated for such work, but because they are the designated lead agencies it is often impossible to get money from alternate sources to work on problems in which the lead agency has no interest. The best scientists are disenchanted by the necessity to deal with managers who simply don't understand the subtleties of the problems they are empowered to solve. The responsibility for basic research must be wrested from these agencies and placed in an organization which is dedicated to basic research on the environment and isolated from immediate political pressures.

I am not suggesting that this would be accomplished by simply increasing the NSF budget. NSF is not set up to put strings on the use of its funds. Nor should it be. To do the kind of environmental research which will be required if we are to effectively deal with long term environmental problems, there must be some strings. I think that scientists working on the ocean and atmosphere have learned the value of coordination in working toward goals which are unachievable by the efforts of individual research groups or even by individual nations.

In an addition to more resources and better management, we need many more properly trained scientists in this area. Such a cadre is best produced by a carefully sequenced program of graduate fellowships, post doctoral fellowships and career research positions.

While in this decade of budget deficits it may be unrealistic to call for new government entities, I am convinced that the only sure road to

straightening out the mess which exists in the area of environmental research is to create a national institute dedicated to this endeavor. This institute would have a twofold objective. First, it would provide funding and coordination of environmental training and research in universities. Second, it would provide the advice to the government on a broad range of environmental questions.

I emphasize university involvement for it is in this setting that excellent research is generated for a minimum cost. By housing graduate education, post doctoral training and research under one roof, an optimum environment for both training and research is created. The housing of environmental research in large laboratories operated by government agencies has. with a few outstanding exceptions, proven to be nonproductive and wasteful.

There are, however, two kinds of efforts which require facilities not available to universities, one of these is satellite observations which will be the cornerstone of our effort to monitor the system we seek to understand. Such platforms are best operated by NASA (or NOAA). The other is the very large climate models which are now the basis for all climate prediction. These facilities require large research staffs and megacomputers. Fortunately, a successful format has already been found. NASA bases such an effort on Columbia's campus. NOAA locates its primary effort on Princeton's campus. NSF has established an institute for joint university research at the National Center for Atmospheric Research in Boulder. Because of the enormous importance of these so-called "general circulation models" to climate prediction, these existing labs must be strengthened. Also, similar efforts must be launched in University settings.

As far as specific areas in which our efforts must be greatly expanded, the five listed below can be singled out for special attention.

1) The large scale circulation of the ocean.
2) The processes regulating soil moisture.
3) The processes responsible for cloud formation.
4) The influence of global biogeochemical cycles on the atmosphere's composition.
5) The processes regulating sea ice.

Of course, programs already exist in all these areas, but in my estimation they will not bring the desired answers on the appropriate time scale. In each area we need major new observational programs to supply key data needed to develop a better physical understanding. In each area we need a cadre of young scientists with the appropriate training.

We also need to intensify our study of climate changes which have taken place over the last 100,000 years. As discussed above, nature on her own has conducted climate experiments of large magnitude. The response of the system to these natural experiments is recorded in sediments and in ice. By thoughtful study of these records, we will be able to learn valuable things about the interactions which link the various major elements of the Earth system. I would like to stress once again that it is changes in these linkages which are likely to carry the greatest threats.

SUMMARY

While we don't know nearly enough about the operation of the Earth's climate system to make reliable predictions of the consequences of the greenhouse buildup, we do know enough to say that these impacts are potentially quite serious. Regardless of the scenario adopted, it seems to me

that the Earth's remaining wild life will be dealt a serious blow. If, as the climate record in ice and sediment suggests, climate changes come in leaps rather than gradually, then the greenhouse buildup may threaten the continuity of our food supply. To date, we have dealt with this problem as if it's impacts would come in the sufficiently distant future and so gradually that we could easily cope with them. While this is certainly a possibility, there is, I believe, an equally large possibility that the impacts will be considerably more dramatic. Hence, we must pull our heads out of the sand and deal with the climate problem as with the cancer problem and nuclear defense problem. As there are no quick fixes or easy solutions, we must gear up for the long hard job of figuring out how the Earth system operates. To do this will require not only more financial and human resources, it will also require a management scheme appropriate to the task. Not only do our current managers not have a proper intellectual grasp of the problem, but they are obsessed with legislatively imposed "five year reports", and give little attention to developing a long term strategy to build the needed base of knowledge. Even with a great intensification of effort, I fear that the greenhouse impacts may come largely as surprises. However, the greater our knowledge, the greater the wisdom will be brought to bear if surprises do come.

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February 9, 1987

Senator George J. Mitchell
United States Senate
Committee on Environment and
Public Works
Washington, D.C. 20510-6175

Dear Senator Mitchell,

In response to your questions in connection with my greenhouse testimony:

Question 1) You hypothesize that the Earth may experience climate changes so sudden and dramatic that we will have no opportunity to adapt or anticipate. In what time-frame might these sharp jumps occur? Should we be preparing ourselves in terms of the next few decades or centuries?

Answer 1) Unfortunately, the record of climate over the last several hundred thousand years provides no analogue to the warm climates to be created by the greenhouse buildup. Thus, I cannot say whether the jumps in climate seen during the transition between glacial and interglacial time will characterize transition to the coming superinterglacial. However, if the climate system does change mainly through reorganization, then it would be fair to say that a jump should occur sometime during the next 100 years. Our preparation for such an eventuality must be a continuing effort. As with cancer, we are not likely to gain the answers we seek in the next 50 years. Rather, we must put forth our best effort to gradually push back the walls of ignorance concerning the operation of our environmental system. Each increment of knowledge we put in the bank will put us in a better position to cope with the coming impacts.

Question 2) Is it possible that global climate could change in such a way that some regions of the world might end up substantially cooler at the same time that the Earth as a whole warms up?

Answer 2) This is possible but not very likely. However, the coming warming will likely have a complex regional pattern of effects.

Question 3) What is your view of the Department of Energy's Carbon Dioxide Research Program? In your written testimony on page 14, you refer to the handling of this program as a disaster. What specific improvements do you view as most critical for this program, particularly in the immediate, short-term?

Answer 3) Senator Chafee asked a similar question. Rather than repeat my answer to him I will amplify on it a bit. The DOE program is directed toward a quick fix. The assumption is that most of the facts are in and hence, what remains is to properly massage them. I strongly disagree. Most of the juice has already been squeezed from the existing facts. Further massaging will lead to little improvement of our ability to predict what is to come. If we are to advance, we must learn more about the ocean, clouds, soils, etc. Unfortunately, this requires large and expensive observational programs.

As far as improving the DOE program; there is only one solution. Replace the current manager with a highly iespected scientist known for his or her knowledge of the ocean-atmosphere system. Give this manager free rein to develop a long term program isolated from immediate political interference. I seriously doubt whether DOE can be trusted to do this task. It would be far safer if the program were transferred to an entity dedicated to the long term study of our planet's environment and the problems which man inflicts upon it.

Question 4) Could you elaborate briefly on your concept for a national institute for environmental research?

Answer 4) There are three primary tasks necessary to the furtherance of our knowledge of the environmental system. One involves the gathering of global data sets. The second involves radical improvements to existing climate models. The third involves the study of the climate record for the last few hundred thousand years. These tasks must be managed with wisdom. It is all too easy to spend millions of dollars gathering the wrong data or inadequate data. Model development must be a patient process undertaken by scientists of the highest quality. The study of the climate record involves expensive drilling programs on the polar caps. All require the cooperation between government agencies and university scientists. The proposed institute would be charged with defining the targets and developing the needed programs. The institute would have to be more than a coordinator for without its own budget it would have no muscle. The groundwork for these efforts has been laid by the U.S. plan for an International Geosphere-Biosphere Program. What remains is a mechanism to implement the kinds of research outlined in this document. I pray that this will not be done by passing out dollars to each of the existing entities. Rather, it should be implemented through a new entity dedicated to understanding the operation of our planet's environmental system.

Sincerely,

W.S. Broecker

WSB:vc

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Senator John H. Chafee
United States Senate
Committee on Environment and
Public Works
Washington, D.C. 20510-6175

Dear Senator Chafee,

In response to your questions in connection with my greenhouse testimony:

Question 1) On page 14, you state that the handling of research on greenhouse gases by the Department of Energy has been a disaster. Could you supply details for the record?

Answer 1) Fred Komanoff, who directs this program, does not have a sufficiently deep understanding of the greenhouse problem to make proper use of the program's resources. He does not realize the importance of building an understanding of how our environmental system is engineered. Only in this way will our ability to cope with the changes the greenhouse buildup is bound to bring be fortifiied. Instead, he is obsessed with data banks, cooperation with the Chinese, interim reports, etc. One episode close to my heart provides an example of Fred Koomanoff's poor judgement. Despite constant urging to support the U.S. effort to map the movement of anthropogenic tracers (freons, tritium, radiocarbon, etc.) into the sea's interior, Fred withdrew DOE support claiming that these programs are too expensive. He did this despite the universal agreement that an ocean component must be added to current climate models and that tracer information is the single most important means of validating such models. Fred's withdrawal of DOE funds set the U.S. tracer program back about five years, and created great turmoil for those involved in this enterprise. Only in the last 6 months has the program finally gotten back on track. The financing is now 100% NSF. I suspect that Fred uses the $800,000 per year item which Dave Slade, his predecessor, had set aside for ocean tracer work to operate his ill fated data bank.

Question 2) To what do you attribute this mishandling?

Answer 2) I attribute this mishandling to DOE's selection of a manager rather than a scientist to direct the nation's CO_2 progam. Further, the manager selected has alienated the nation's best scientists in this area. Thus, he is denied the advice they could give regarding the proper structuring of this important program.

Question 3) Assuming we did set up a new "national institute of environmental research", as you suggest, what makes you think the same managers who handle research now wouldn't just move to the new agency?

Answer 3) The new institute would be governed by a board of directors made up of prominent scientists. This board would set the institute's policy and select its director. The director would presumably be a scientist skilled in management (rather than a manager unskilled in science).

Sincerely,

W.S. Broecker

W.S. Broecker

WSB:vc

TESTIMONY

of Dr. Tom M. L. Wigley

Presented on January 23, 1987, to the Subcommittee on Environmental Protection, Environment and Public Works Committee, hearing on "The Greenhouse Effect and Climate Change."

Mr. Chairman,

Thank you for inviting me to appear before you today. My name is Dr. Tom Wigley and I am Director of the Climatic Research Unit, University of East Anglia, Norwich, United Kingdom. I am currently a Visiting Scientist at the National Center for Atmospheric Research, Boulder, Colorado.

My testimony concerns the observed global warming that has occurred over the past 100 years. I will summarize how this temperature record was obtained and describe the details of the record with particular reference to the most recent decades and to the differences between the records for Northern and Southern Hemispheres. I will then compare the record with the predicted warming over the same period due to the effects of increasing greenhouse gas concentrations in the atmosphere. Finally, I will compare the projected warming over the next 70 years with global temperature changes that have occurred over the past few million years.

Global-mean temperature is the best single indicator of the state of the Earth's climate. To obtain a true, global record, we need to consider temperature changes over both the land masses and the oceans. The latter are particularly important because they cover more than 70% of the Earth's surface. I will consider the land masses first.

Temperature changes over the land areas differ considerably from place to place and region to region. These spatial differences, which come about because of the complex patterns of the atmospheric circulation, are an important facet of the climate system's natural variability. We eliminate these complexities by averaging over large areas. The data we use are from the many national networks of weather stations coordinated by the World Meteorological Organization. Prior to the establishment of these networks we use data collected by scientific organizations and by individual scientists and amateur meteorologists. Some of these early records go back into the late 17th century. In our analyses we have examined data from more than

3300 sites, corresponding to a total of well over 100 million individual observations.

To produce a reliable area average for the land masses, we need to ensure two things, accuracy of the individual site records, and adequate spatial coverage.

To check the accuracy of individual site records, each record must be examined in detail and compared with records from nearby sites. When records are found to contain inaccuracies (which may result from site changes, instrument changes, changes in observation practices, etc.) they are either corrected or discarded. One particular problem is that stations located in urban areas tend to be affected by the warmth that is generated by human energy consumption, the "urban warming" effect. Stations showing an urban warming effect have not been used in our analysis.

Adequate spatial coverage is necessary to ensure that any calculated area-average temperature is representative of the whole landmass area. Adequacy of spatial coverage can be tested by comparing the results based on the present-day network of stations with averages based on only a subset of the currently available network. Such comparisons show that averages for the Northern Hemisphere land masses are reliable back to about 1875, while averages for the Southern Hemisphere land masses are reliable back to about 1890. In the Southern Hemisphere, data for Antarctica extend back only to the late 1950s, but this part of the globe covers such a relatively small area (less than 5% of the Earth's total surface area) that the absence of Antarctic data prior to the late 1950s cannot noticeably affect the global or Southern Hemisphere mean.

Temperature changes over the ocean areas are not so spatially variable as those over the land. The data we use are from ships which transmit meteorological information routinely to form part of the World Meteorological Organization's world weather watch system. This material has been collected together to form a data set called the Comprehensive Ocean Atmosphere Data Set, COADS. COADS contains more than 60 million observations of sea surface temperature and an equivalent number of marine air temperature observations. A similar data set has been compiled by the United Kingdom Meteorological Office, but we have used COADS which has been compiled by U.S. scientists.

These ocean data cannot be used in their raw form--they need first to be adjusted to account for changes in measurement techniques that have occurred over the past 100 years. The major factor here is that early observations of sea surface temperature were made using water samples collected in canvas buckets, whereas most modern observations are made on the water which enters the ship for engine cool-

ing. Corrections must be applied to account for the systematic difference between these two types of measurement. This can be done by comparing the marine data with land-based observations in coastal regions or in the vicinity of islands. Correction factors so derived can then be applied to the rest of the data set.

As with the land data, there is a problem of inadequate spatial coverage in the early years of the marine record. Although our data go back to 1861, the area averages may not be representative of the whole ocean area, at least for the first few decades. Paradoxically, in these early decades, there is good coverage in some regions where coverage today is poor. A particular case in point is the southern Pacific, which became less travelled after the opening of the Panama Canal. Overall, coverage is generally adequate after the late 19th century, except in the southeastern Pacific and in ocean areas south of about 45°S. These gaps represent only about 10% of the area of the Earth's surface and so cannot significantly affect the area averages.

To summarize, the data available allow us to estimate global- and hemispheric-mean temperatures back to the late 19th century with considerable reliability. Less reliable estimates can be made back to 1861. The results are shown in Figure 1.

Figure 1 shows the following:

(1) The globe has warmed by about 0.5°C (0.9°F) over the past 100 years. The globe is certainly warmer now than it has been at any time since the beginning of the era of instrumental meteorology, and probably warmer than it has been for many thousands of years (see below).

(2) This warming is common to both hemispheres, and is common to both land and ocean areas.

(3) Superimposed on this overall warming trend, there are noticeable fluctuations on shorter time scales. These year-to-year and decade-to-decade fluctuations are aspects of the natural variability of the climate system, variability that occurs even in the absence of any external forcing.

(4) The longest and most important of these fluctuations is the cooling which occurred in the Northern Hemisphere between about 1940 and 1970. This cooling is much less noticeable in the Southern Hemisphere.

(5) Between 1976 and 1981, the Earth experienced a period of very rapid warming, with a levelling off of this upward trend in the past few years. 1983 and 1981 are the two warmest years in the entire record.

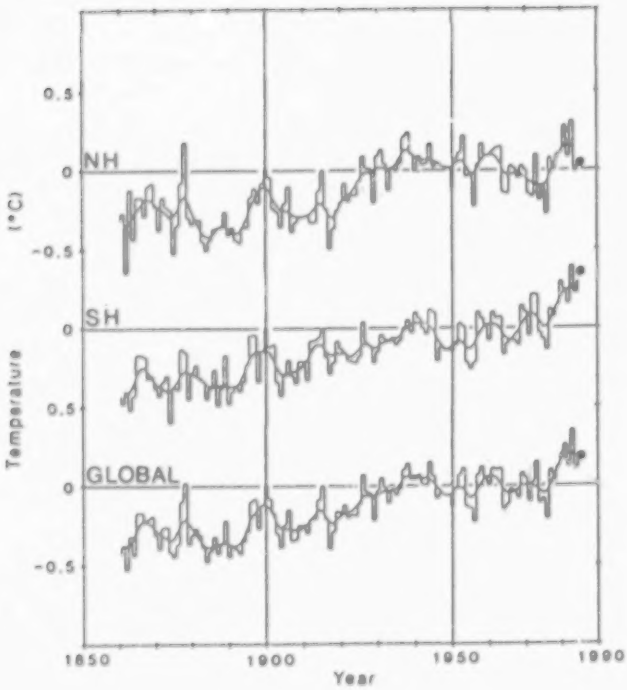

Figure 1. Observed changes in temperature for the Northern Hemisphere (NH), Southern Hemisphere (SH) and the globe. The values shown are averages over both land and ocean areas. The smooth curves are filtered values designed to show the longer time scale changes more clearly. Values prior to about 1900 are less reliable than those after 1900. This diagram is the same as that published in the journal Nature (P.D. Jones, T.M.L. Wigley and P.B. Wright, Nature, Vol. 322, pp. 430-434, 1986) except for the final dots which show preliminary values for 1985.

What are the causes of these observed temperature fluctuations? At present we can provide only a partial answer to this question. Global mean temperature can vary for any of a large number of reasons. These can be grouped into external and internal factors (although sometimes the distinction between external and internal is not so clear).

External factors include changes in the Sun's energy output (i.e. solar irradiance), changes in the transparency of the atmosphere to incoming solar radiation (as may result from the changes in stratospheric aerosol concentrations that follow explosive volcanic eruptions), changes in the atmospheric concentrations of greenhouse gases (in particular, carbon dioxide, methane, nitrous oxide, ozone and chlorofluorocarbons), and changes in the Earth's surface reflectivity (or albedo). This last factor includes the effects of varying snow and ice cover. Such influences could also be considered internal factors.

Other internal factors include changes in cloudiness and changes in the ocean circulation, particularly the vertical components of the circulation. Vertical circulation changes in the ocean lead to a redistribution of heat within the ocean-atmosphere system. The El Nino/Southern Oscillation (ENSO) phenomenon is an example of such a change. A more important example as far as long-time-scale temperature changes are concerned is the rate at which cold, dense water sinks in high latitudes, particularly in the North Atlantic (this process is referred to as deep water formation). If the rate of North Atlantic deep water formation is reduced, this can cause a net cooling in high northern latitudes which may noticeably affect global-mean temperatures.

Of all of these forcing factors, only one has a well-established history, namely greenhouse gas concentrations. Our knowledge of past solar irradiance changes prior to about 1970 is very sketchy and uncertain. For volcanic forcing, although we probably know all of the big eruptions that have occurred during the past 100 years or so, we are still uncertain of the quantitative effects that these eruptions have had on atmospheric transparency, especially on decadal and longer time scales. Knowledge of past ocean circulation changes associated with deep water formation is almost non-existent: we know that changes <u>have</u> occurred, but we know practically nothing of the timing or magnitude of these changes.

I will therefore consider only the greenhouse gases. For these, we know the concentration changes quite well for the past 200 years or so, both from direct measurements in the atmosphere and from measurements of their concentrations in bubbles trapped in high latitude ice masses. However, while this aspect of the forcing is known, the response of the global climate is clouded with uncertainty. To

estimate this response we must use mathematical models of the atmosphere-ocean system, climate models. Such models are still undergoing development and are currently the focus of intense scientific research.

In studies of the greenhouse effect, one of the most important factors that these models must take into account is the damping effect of the oceans' thermal inertia. This slows down the response of the climate system to external forcing so that, at any given time, the actual response lags behind the potential response. A consequence of this lag effect is that, even if we could halt the increases in greenhouse gas concentrations today, the globe would continue to warm for many decades before it reached a new equilibrium state.

In Figure 2, I show model-based estimates of the greenhouse-gas-induced warming back to 1765 and projected forward to the year 2050. It is important to realize that these changes are not due solely to carbon dioxide, but also to the almost equally important effects of changes in the atmospheric concentrations of methane, nitrous oxide and chlorofluorocarbons. The temperature projections shown in Figure 2 are based on estimates of future greenhouse gas concentrations. These estimates are, themselves, subject to considerable uncertainty; indeed, we potentially have the power to exert some control over these future concentrations.

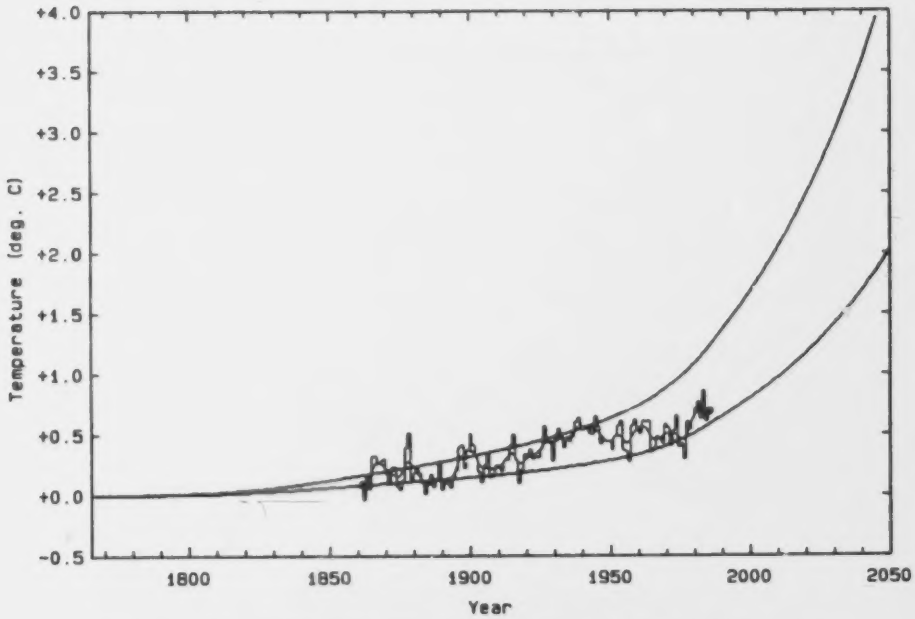

Figure 2. This figure shows predicted values of global warming due to observed changes in greenhouse gas concentrations from 1765 to the present, together with projections forward to the year 2050 based on estimated future greenhouse gas concentration changes. For future concentrations, intermediate values from the ranges given by V. Ramanathan, R.J. Cicerone, H.B. Singh and J.T. Kiehl, Journal of Geophysical Research, Vol. 90, pp. 5547-5566, 1986 were used. The range of values between the upper and lower curves reflects uncertainties in the climate system's equilibrium sensitivity to greenhouse gas concentration changes. The shorter record between the limiting curves is the observed global-mean record from Figure 1. Note that the values shown are only relative changes. For the model results the zero-point is the 1765 value. For the observations, the zero-point in Figure 1 is the 1950-79 average. The zero-point for the observations has been raised here in order to make model results and observations directly comparable. The model used was a box-upwelling-diffusion energy-balance climate model with a diffusivity of 1 $cm.^2$/sec. and an upwelling rate of 4 m./yr.

It is clear from Figure 2 that the observed century-time-scale warming is consistent with the model estimates of greenhouse-gas-induced warming. This does not mean that we have proved that the warming is due to anthropogenic greenhouse-gas concentration changes. Because the climate system exhibits a considerable degree of natural variability, because our models of it are still somewhat rudimentary (albeit themselves so complex that they often require the largest computers for their operation), and because we know that there are other possible explanations for the observed warming, proving a cause-effect link is exceedingly difficult. We do know for certain that the world has warmed, but we can only say at this stage that the magnitude of the warming is consistent with greenhouse hypothesis, not that this hypothesis has been proven beyond doubt.

On time scales less than the 100-year time scale, there are obvious discrepancies between the observed temperature changes and those predicted by the model. These discrepancies reflect the natural variability of the climate system. A large part of this variability may be due to the other external and internal forcing factors listed above, but we cannot be sure of these linkages because we do not know the past histories of these other forcing factors sufficiently well. Nevertheless, I will outline some of the possible explanations.

(1) Some of the decadal and shorter time scale changes can be convincingly connected with ENSO events, while others coincide with major volcanic eruptions. ENSO effects and the short-term effects of such volcanic eruptions are quite well established.

(2) The 1940-70 flattening of the global temperature curve coincides with suspected variations in solar irradiance, but the link here is still speculative. The cooling of the Northern Hemisphere relative to the Southern Hemisphere between 1940 and 1970 (and earlier examples of such relative changes) may be due to relative albedo or cloudiness changes, or to changes in the vertical circulation of the North Atlantic Ocean. In the absence of firm data on any of these potential forcing factors, however, all three explanations, while physically plausible, must remain speculative.

(3) The rapid warming in the late 1970s, too rapid to be due to greenhouse gas effects alone, corresponds to a period during which an increase in solar irradiance was observed. Since 1979, solar irradiance has declined. This rapid warming and the subsequent levelling off of the temperature rise may, therefore, reflect combined solar and greenhouse gas effects. However, the effects of the eruption of the volcano El Chichon and of the 1982/83 ENSO event have also contributed to climatic fluctuations during the 1980s.

The tentative nature of the above suggestions serves to show the current state of the art in our understanding of the workings of the climate system; but it also reflects a lack of suitable data with which to test our hypotheses.

The future greenhouse-gas-induced warming between now and 2050 shown in Figure 2 lies between 1.4 and 3.1°C (i.e., 2.5 to 5.6°F). The range of uncertainty may well be even wider than this because uncertainties in future greenhouse gas concentrations have not been taken into account. What is certain is that, if greenhouse gases are responsible for the 20th century warming, then, no matter what their future changes, future warming is inevitable. This is a direct consequence of the lag effect of oceanic thermal inertia described earlier. Because of this, and because the greenhouse gas projections at least to the year 2000 are unlikely to be grossly in error, the model-based temperature projections through to the early decades of the 21st century must be regarded as realistic scenarios for the future.

Just what do these projected future changes mean in the context of the natural variability of global climate over past millions of years? Even today, conditions are as warm as they have been for many thousands of years. Some 6,000 to 9,000 years ago, there is evidence that the Earth may have been up to 0.5°C warmer than today. Based on so-called "proxy" evidence from past vegetation distributions, we know that parts of the Northern Hemisphere were noticeably warmer then compared with today, but we do not really know what the global-mean temperature was at this time. Going farther back in time we soon encounter the opposite climatic conditions, the extreme cold of the last ice age (which climaxed some 15-20,000 years ago). At this time the Earth was 3-4°C colder than today, a negative perturbation whose magnitude may be compared with the projected positive perturbation of 1.4-3.1°C for the middle of the 21st century. Going back still further into the past, the next warm period occurs around 100-130,000 years ago. The global-mean temperature then was similar to today, probably a little warmer. To find widespread and sustained conditions comparable with those that could occur by the mid-21st century, we have to go back much further in time, almost certainly more than two million years. It is clear, therefore, that if the greenhouse effect is of the magnitude predicted by today's climate models, then, by the early decades of the 21st century, mankind will be living in a world whose climate differs radically from anything in human memory.

I will conclude by summarizing the main points made in this testimony.

(1) The globe has warmed by approximately 0.5°C over the last 100 years.

(2) The magnitude of this warming is consistent with the predicted warming due to changing atmospheric greenhouse gas concentrations.

(3) Although the greenhouse effect cannot yet be claimed to have been detected unequivocally, the predicted warming over the next few decades is such that positive identification is likely within the next 10-15 years.

(4) To ensure this detection, the present global network of meteorological observations must be maintained. In some data-poor areas, improvements in the network would be advantageous. Other possible causal factors must also be continuously monitored.

(5) If the magnitude of the greenhouse effect is as models predict, then, in the absence of other unexpected external forcings, unprecedented climatic conditions can be expected by the early decades of the 21st century, or sooner.

The observational and modeling results summarized in this testimony encapsulate the work of many scientists. I acknowledge particularly the contributions of my colleagues, Drs. P. D. Jones, P. M. Kelly and M. E. Schlesinger.

Testimony for

Subcommittee on Environmental Protection
Committee on Environment and Public Works
United States Senate

Presented by

Dr. Ralph J. Cicerone, Director
Atmospheric Chemistry Division
National Center for Atmospheric Research
Boulder, Colorado 80307

January 23, 1987

In the time you have given me today I will try to cover three topics of interest to the Committee: greenhouse gases and their histories and futures, the relationship between the greenhouse effect and ozone depletion and the connections between the causes of the greenhouse effect and acid deposition.

Gases Involved in the Greenhouse Effect

Scientists now know enough about the properties of chemicals that can be effective greenhouse gases that we can list the potential key contributors to the effect and we can dismiss many other chemicals that do not possess the right properties. In the table of data that accompanies the written text of my testimony, I summarize data on greenhouse gases that are actually piling up in the atmosphere. I will read the lines and in between the lines of that table now. You will see that the composition of the atmosphere and hence the greenhouse radiative forcing of the system are entering into uncharted territories.

Carbon dioxide now comprises 346 parts per million (ppm) of Earth's atmosphere. In the pre-industrial era its concentration was about 275 ppm, according to measurements of old air that was taken from ice cores. This 25% increase during the last 100 to 150 years is almost certainly due to our burning of fossil fuels (coal, gas, oil) although part may be due to the decay of organic material following deforestation. Carbon dioxide concentrations are now higher than at any previous time in the last 40,000 years. During that epoch, and possibly for the last 300,000 years, carbon dioxide concentrations have moved between 180 ppm and 300 ppm, never as high as now. There are suspicions that carbon dioxide values were much higher than at present when Earth was considerably younger, several billion years ago, for example.

When carbon dioxide is measured one finds seasonal variations and slightly different values at different locations. Generally, the rate of increase of CO_2 is about 4% per decade; again, this rate varies from year to year. Up to now and for the next 20 years or so, these

Gas	Concentration in Air Pre-Industrial	1986	Present Rate of Increase (per year)
Carbon dioxide, (CO_2)	275 ppm	346 ppm	1.4 ppm (0.4%)
Methane, (CH_4)	0.75 ppm	1.65 ppm	17 ppb (1%)
Fluorocarbon-12, (CCl_2F_2)	Zero	400 ppt	19 ppt (5%)
Fluorocarbon-11, (CCl_3F)	Zero	230 ppt	11 ppt (5%)
Nitrous Oxide, (N_2O)	280 ppb	305 ppb	0.6 ppb (0.2%)
Ozone, Tropospheric (O_3)	15 ppb?	35 ppb	0.3 ppb? (1%) Northern Hemisphere Only
Other Fluorocarbons	Zero	see text	(5 to 15%)

Table 1. Key greenhouse gases—present concentrations in air, rates of increase and pre-industrial era concentrations. ppm = parts per million, ppb = parts per billion, ppt = parts per trillion.

CO_2 increases account for half or more of the global human-induced greenhouse effect. Future values of atmospheric CO_2 will depend on fuel usage and type, details of exchange with the oceans, and biospheric growth and decay rates. A doubling of pre-industrial CO_2 concentrations is not unlikely to occur in 100 to 150 years.

Methane concentrations have risen about 100% in the last 150 years or so, from 0.75 ppm to 1.66 ppm. The last 35 years have seen a 30% to 40% increase. There is no evidence that methane concentrations were ever as high as they are now although it is possible especially for the primitive Earth. The lower pre-industrial concentrations probably represent natural, unperturbed background levels of this familiar gas. Swamps, marshes and tundra are natural sources of methane ("swamp gas") and natural gas venting is possibly significant (methane is the principal component of natural gas.) Human activities are quite capable of having caused these recent methane increases and of continuing such a trend into the future. Humans increase the sources of atmospheric methane by expanding rice agriculture and herds of ruminant animals and by increased coal mining and natural gas drilling and transmission, and possibly by increased usage of landfills as garbage dumps. We may also be suppressing the atmosphere's natural ability to assimilate methane by dumping more pollutants like carbon monoxide into the air. As the climate warms we should be aware of the possibility of accelerated methane releases from tundra and from oceanic methane clathrates.

The two principal fluorocarbons that are implicated in the greenhouse effect and stratospheric ozone depletion are fluorocarbon-12 and fluorocarbon-11, CCl_2F_2 and CCl_3F, respectively. These are totally synthetic chemicals so neither of them were present in the pre-industrial atmosphere. Fluorocarbon-12 now comprises 400 ppt of the atmosphere and fluorocarbon-11, 230 ppt. These concentrations sound small but both of these chemicals are such potent greenhouse gases and the chlorine atoms that are released from fluorocarbon-12 and -11 in the stratosphere have such large potential for destroying ozone that global

effects are of concern. Also, their concentrations have been growing at rates of roughly 5% per year.

Future increases in atmospheric fluorocarbon concentrations are fully expected. Even if emissions do not increase further, concentrations will increase for the next several decades because of the long time needed for atmospheric destruction processes to equilibrate with a steady input. Emissions to the atmosphere will increase if industrial production and usage increase—there are economic projections that show a continued or growing demand for these chemicals (or possible substitutes) as refrigerants, aerosol propellants, foam-blowing and degreasing agents, and as cleaners or solvents. Without international regulations, the emissions of these chemicals could increase by 2% to 5% annually.

In the case of nitrous oxide (laughing gas, N_2O) we are unsure as to why it is increasing but measurements from all over the world have established that it is. The 1986 concentration of N_2O was about 305 ppb. Pre-industrial nitrous oxide concentrations were about 280 ppb. Presently, N_2O concentrations are increasing at about 0.2% per year. This rate might sound small to you but it actually signals a large global perturbation in the source of N_2O. It takes 5,000,000 extra tons of N_2O annually to cause this increase; whatever the identity of this extra source it is now about 25% as big as the total of all natural sources. Two possible N_2O sources seem likely. One is the inadvertent loss of artificial nitrogen fertilizer from fertilized fields and from subsequent nitrogen cycling in food and wastes. Some N_2O escapes into the air from soils and water bodies during two processes of nitrogen cycling: nitrification and denitrification. The second candidate as an N_2O source is the combustion of nitrogen-rich fuels; the higher the nitrogen content of various fuels, the more the N_2O production, it appears. World demand for N fertilizers keeps growing. In 1950 only about 3,000,000 tons were produced. In recent years the annual total was over 50,000,000 tons. Similarly, as you know, fuel combustion increases at 2-4% per year although the mix of fuels varies and the rates track the general economy.

Tropospheric (lower atmospheric) ozone is potentially an important greenhouse gas. Measurements show that tropospheric ozone is increasing in concentration in the Northern Hemisphere (where there is more human influence), perhaps 1% per year but the situation is not as clear as for other greenhouse gases. Ozone is nowhere near as inert or long-lived as the others; a blob of ozone-rich air can decay, not just by dilution but also by chemical reactions and contact with surfaces. With only a 100-day lifetime, tropospheric ozone is more variable from place to place and season to season so it's not possible to give one number for a global ozone concentration or rate of change. There are new indications from European scientists that background ozone concentrations at the turn of this century were well below those at present, perhaps only one third as large. More on ozone later.

Other fluorocarbons and chlorocarbons deserve some note. Greenhouse contributions from trichloroethane and carbon tetrachloride are recognized but for other chemicals, for example fluorocarbon-113, whose usages and atmospheric concentrations are growing fast very little attention has been paid so far, i.e., their atmospheric concentrations and rates of change are poorly known as are some of their infrared properties.

The Greenhouse Effect and Stratospheric Ozone Depletion

An important relationship exists between the causes of the global greenhouse effect and the depletion of stratospheric ozone: the key greenhouse gases fluorocarbons-12 and -11, nitrous oxide and methane also affect stratospheric ozone strongly. These gases have atmospheric survival times long enough to permit them to make the upward journey into the stratospheric ozone layer. In the harsh ultraviolet light there the fluorocarbons are decomposed yielding chlorine atoms that destroy ozone. Nitrous oxide decomposition yields nitric oxide that acts similarly. Methane acts to slow the attack on ozone but it also decomposes to yield molecular fragments that are involved in ozone destruction. Interestingly, present models say that the chlorine attack on ozone is slowed somewhat if in the future nitrous oxide and methane continue to increase along with the fluorocarbons.

The slower decrease of total ozone will result in a redistribution of ozone toward lower altitudes.

Carbon dioxide is not involved chemically but once in the upper atmosphere it acts to cool the air by radiating energy to space. This cooling should also act to slow the chlorine attack on ozone a little.

Another connection arises because stratospheric ozone itself can affect temperatures at the surface of the Earth. If, for example, the fluorocarbons, nitrous oxide and methane all increase in the future there should be more ozone present in the lower stratosphere and a warming should occur.

More complicated phenomena may be occurring over the Antarctic where springtime ozone concentrations have decreased greatly in the past fifteen years or so. The same ozone-destroying chemicals just mentioned are probably at play but through more complex pathways, I believe. In any case it is very important to learn the mechanism behind the formation of this Antarctic ozone hole if we want to be able to predict whether the hole will worsen and spread north or whether it will stay over Antarctica or even disappear. Of all the gases relevant today, the fluorocarbons stand out in several ways. Their concentrations in the atmosphere are the smallest, their annual percentage rates of increase are the largest and their sources are the simplest to understand; they are manmade. Ten years ago CCl_3F and CCl_2F_2 were used mostly as aerosol propellants and as refrigerants and the U.S. accounted for about half the total world production and usage. Now the aerosol application represents a smaller proportion, especially in the U.S., and the U.S. production and usage is a smaller part of the world's. Recently, two U.S. industrial groups proposed that international agreements be sought to limit the future growth of emissions to the atmosphere. In this way steps could be taken to contain future greenhouse and ozone-depletion effects.

Acid Deposition and Greenhouse Gases

The relationships between regional acid deposition and the global greenhouse effect are not as direct as for the greenhouse effect and stratospheric ozone depletion. The strong acids in precipitation, sulfuric, nitric and formic, are formed from emissions of sulfur dioxide, nitrogen oxides and hydrocarbon pollutants. These pollutants are generally short-lived compared to greenhouse gases. None of these pollutants are effective greenhouse gases although nitrous oxide is often formed in the same processes that produce the more common nitrogen oxides. Of the key greenhouse gases only tropospheric ozone is involved in the formation of atmospheric acids.

A strong and broad link between the two phenomena is made, however, through the chemistry of the atmosphere. Hydrocarbon and nitrogen oxide pollutants react to produce ozone. All of these plus carbon monoxide control the rates at which acids are formed by oxidation and they also set the levels of other oxidants, like OH radicals, that bear the atmosphere's ability to oxidize and decompose methane. It is possible that the buildup of methane stems partly from the effects of other pollutants on the whole system. The oxidizing power of the atmosphere is the link and at this time we do not understand very well at all how the chemistry of the troposphere where much of this oxidizing power appears.

QUENTIN N. BURDICK, NORTH DAKOTA, CHAIRMAN
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United States Senate

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
WASHINGTON, DC 20510-6175

January 30, 1987

Dr. Ralph Cicerone
National Center for Atmospheric Research
P.O. Box 3000
Boulder, Colorado 80307

Dear Dr. Cicerone:

Thank you for appearing before the Subcommittees on Environmental Protection and Hazardous Wastes and Toxic Substances on January 28, 1987. Your testimony was extremely important to informing the Senate, and in establishing the record on the scientific understanding of the greenhouse effect and climate change.

The members of the Subcommittees have additional questions, which we are forwarding with this letter. The Subcommittees would appreciate your written response to these questions within two weeks so that they can be made a part of the official hearing record.

Thank you again for your contribution to our deliberations on these important environmental issues.

Sincerely,

Max Baucus
Max S. Baucus

George Mitchell
George J. Mitchell

SENATOR MITCHELL

1) Why is carbon monoxide important in the greenhouse effect? Is it increasing globally? If so, why should we be considered?

2) How fast is methane increasing? Is it possible that a global warming could liberate methane stored beneath the oceans or in the Arctic?

3) Could you give a brief summary of the scientific aspects of the ozone depletion problem?

4) What observations lead you to believe that ozone in the lower atmosphere or troposphere is increasing globally? What are the possible sources of the global increase in ozone?

5) Could you identify what you consider to be the research priorities for the greenhouse effect, climate change and ozone depletion?

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25 February 1987

Senator Max S. Baucus
Committee on Environment
and Public Works
United States Senate, Dirksen 410
Washington, DC 20510-6175

Senator George J. Mitchell
Committee on Environment
and Public Works
United States Senate, Dirksen 410
Washington, DC 20510-6175

Dear Senators Baucus and Mitchell:

This letter replies to your letter of January 30, and the five questions that were transmitted with that letter. I enclose five replies numbered to correspond to your questions. I hope that these replies are useful to you.

Thank you for the opportunity to appear before your Subcommittees on January 28, and for your attention to these issue of global climate change and global ozone depletion.

Sincerely,

Ralph J. Cicerone

Ralph J. Cicerone, Director
Atmospheric Chemistry Division

Enclosures

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1. Carbon monoxide (CO) is not an important direct contributor to the greenhouse effect but it has the potential to accelerate the buildup of other greenhouse gases: methane (CH_4) and ozone (O_3) in the lower atmosphere (troposphere).

   CO is an important chemical reactant in the troposphere; through atmospheric chemistry several interesting feedbacks can arise. First, CO reacts with the all-important hydroxyl radical (OH). If adequate amounts of nitrogen oxides (NO and NO_2) are present, O_3 is formed in the sequence of reactions that begins with CO + OH. Without adequate NO_x, O_3 is consumed in an alternate sequence of reactions. In both cases, atmospheric OH concentrations can be decreased by increasing CO; this occurs when OH and similar radicals combine to form chemicals such as hydrogen peroxide which are susceptible to downward transport and removal, effectively removing OH itself.

   In assessing how CO affects methane and ozone, we need greatly improved data on NO_x in the atmosphere. For most of the global atmosphere, though, increasing CO will decrease OH. This would, in turn, cause methane concentrations to increase even if methane sources do not increase.

   On balance, available evidence from measurements shows that CO is increasing in the global atmosphere at a rate of 0.5% to 2% per year. CO arises from the incomplete combustion of carbon-based fuels but also from some natural plant emissions; the CO increase could arise from either of these or from any decrease in atmospheric OH concentrations. A final comment—when CO is released into the atmosphere instead of carbon dioxide (CO_2) from some combustion process, one might think that this would favor a slower CO_2 buildup. Actually, CO is converted to CO_2 when CO reacts with atmospheric OH.

2. Methane concentrations are increasing at a rate of 1% per year as shown by direct measurements since 1978. Less direct information indicates that a 35% increase has occurred since 1951, a rate that is consistent with the 1978-86 trend. Further, measurements of old air that was extracted from dated ice cores shows that methane concentrations have doubled in the last 150 years or so.

   A global warming could liberate methane that is now stored in oceanic sediments or at depth in tundra. This storage involves clathrates, or cages of ice that trap methane and other hydrocarbons. These clathrates are less stable as temperature increases. Scientists have estimated that substantial amounts of methane could be so released, especially from ocean-shelf sediments, but the exact amounts and the timing of the release are not known. One hundred years or more in the future is a good guess.

3. The key principle that provides the potential for relatively small amounts of chemicals to deplete the ozone layer is known as chemical catalysis. In the last fifteen years or so, scientists have identified the apparently potent catalysts and pathways that deliver such chemicals to the stratosphere where the natural ozone layer resides. Because we want to know exactly how effective ozone-destroying chemicals are, and where and when ozone changes will occur, other aspects of atmospheric chemistry and air motions are strongly involved. These include evaluating how all the chemicals interact in the ozone layer, understanding all ozone production and destruction processes and how atmospheric fluid motions move all these chemicals, both in the unperturbed and the perturbed atmosphere.

   Let me illustrate a few of these points with the example of chlorine from chlorofluorocarbons (CFC's), the two presently dominant CFC's, CFC-12 (CCl_2F_2) and CFC-11 (CCl_3F). The only significant way that nature destroys these synthetic chemicals is with ultraviolet (UV) light. To be exposed to UV sunlight, the CFC's first have to move upward, above most of the ozone layer. There UV light breaks the CFC

molecules, releasing chlorine atoms (Cl). It is well established that all of this occurs. Then the free Cl atoms attack ozone as follows:

$$Cl + O_3 \longrightarrow ClO + O_2$$
$$ClO + O \longrightarrow Cl + O_2$$

$$\text{net effect}: \; O + O_3 \longrightarrow 2O_2$$

In the first reaction Cl atoms destroy ozone to form chlorine monoxide (ClO) + normal oxygen (O_2). In the second reaction, the Cl atom that was consumed in the first reaction is regenerated. So the Cl atom is now free to start the cycle again. The atom of oxygen (O) that disappears in the second reaction is equivalent to an ozone molecule because O and O_2 react quickly to form O_3 normally. Thus, the net effect of these two reactions is to consume two molecules of ozone each time the cycle is repeated. Complications arise because other processes interrupt this cycle and sequester the Cl or ClO into chemical forms that are less available for action. In these less active forms such as hydrochloric acid vapor (HCl), the chlorine can actually be removed from the ozone layer by air motions. It is essential to understand exactly how these interfering processes limit or control the ozone-destroying capability of a Cl atom. Stated differently, scientists are trying to determine which of the various identified processes dominates in distinct spatial locations, seasons and times of day.

In sorting out the exact effects of the main ozone-destroying processes versus those that inhibit ozone destruction or which produce ozone, it has become apparent that the entire complicated system must be understood. For example, Cl atoms can be regenerated from the inactive reservoir species, HCl, if HCl reacts with stratospheric OH radicals before the HCl molecule is transported out of the ozone layer by winds. Scientists do not yet have a reliable data base on OH distributions and how they vary.

A similar, parallel set of questions surround NO_x in the stratosphere (released from nitrous oxide, N_2O) as for chlorine. That is, the ozone-destroying ability of NO_x cannot be evaluated exactly without going into the interactive aspects of the whole atmospheric system. In the case of the ozone depletion over Antarctica, it is likely that the interactions of these gaseous chemicals with each other and with condensed cloud particles, atmospheric radiation and physical properties (temperature, patterns of motion) are all involved.

Laboratory experiments, field measurements and theoretical model calculations all have roles to play in explaining what is going on and in predicting the future. In some cases episodic expeditions can settle questions, but for many other questions long-term observations are needed.

4. Lower atmospheric (tropospheric) ozone is increasing in concentration at the few measurement stations that have gathered good data in the last 10 to 15 years. These data are not as convincing as we would like, but they seem to show a 1% per year increase. Observations from Europe show increases during the 1950's but the proximity of pollution sources confounds the interpretation somewhat. A new, very rigorous and scholarly reconstruction of data from ozone measurements in France near the turn of this century shows that background ozone levels were well less than today, perhaps only one-third or one-half of today's.

   The strongest possibility to explain the ozone increases is that NO_x and hydrocarbon pollutants (that are entering the atmosphere in growing amounts) are reacting through known chemical pathways to produce more ozone. We don't know whether ozone production is greatest near pollution sources like cities or farther downwind in remote areas, nor how effective are NO_x and hydrocarbon emissions from aircraft but two features of the ozone field data do implicate this general explanation. One is that ozone concentrations have increased more in summer months when photochemical

ozone production is easier. Second, the absence of an ozone increase in the Southern Hemisphere, where there is less industry and combustion, is a meaningful sign.

5. My response to this question involves a broad research effort, not because I have tried to create a shopping list but instead because the agenda of needed research is very full now. We have reached this state of affairs by attempting to deal with, actually struggling to deal with, policy aspects of ozone depletion and greenhouse gas effects with partial scientific information since the mid 1970's. All of us suspect that we will never attain a complete understanding of the Earth as a system but the debates in the U.S. over the past ten to fifteen years have shown that much more convincing evidence is needed before policy actions are agreeable to financially affected people and industries, to those who are skeptical philosophically and to scientists who seek substantive understanding.

   As to global ozone depletion, we need atmospheric measurements of key chemical compounds of chlorine, nitrogen, hydrogen and bromine and simultaneous measurements of subsets of these to test our theories of how they interact. We also need a sustained, systematic program of laboratory experiments in chemical kinetics and photochemistry to permit mechanistic understanding of atmospheric transformations. It hardly needs to be stated that ozone monitoring is important worldwide—of total ozone amounts, distributions in latitude and altitude, of trends and variations. And to make sure that we have not overlooked some natural sources of chlorine, it would be good to measure the total amount of chlorine in all forms in the stratosphere. Special focussed expeditions to Antarctica are also needed to try to fathom why ozone changes are occurring there.

   Mathematical modeling of ozone depletion can be greatly improved. Simulating the two-dimensional and three-dimensional air motions and how they interact with added chemicals and with ozone changes is feasible, given extra effort, time and resources.

Modeling the simultaneous future growth in atmospheric CO_2, CFC's, CH_4, N_2O and other chemicals clearly deserves more attention given the likelihood that such increases will continue to occur.

Greenhouse-effect and climate-change research should include field measurements to determine oceanic circulation patterns and details of how the oceans transport heat and nutrients, measurements and interpretation of paleoclimate patterns and changes, and of terrestrial carbon cycling parameters. Careful, sustained monitoring of air and water temperature trends and of sea-level and sea-ice changes is clearly needed. Similar monitoring of the concentrations of greenhouse gases and of stratospheric water vapor (which can vary naturally and affect surface temperatures) is strongly indicated. There are also some laboratory experiments needed to determine the infrared properties of certain CFC's and potential CFC substitutes. We must also find out how cloud amounts and cloud optical properties might change as the Earth warms, and how to model these changes.

Mathematical modeling of climate processes and of future and past climate changes can be greatly improved. Much more focus is needed on the response of selected regions, such as the midwestern U.S., as opposed to simple, global models. We must focus also on climate change in the next two to ten decades, a time period when climate changes of various kinds are anticipated. These kinds of improved modeling are feasible but they require extra effort, time and money.

These research needs add up to a lot of activity in the next several years and even in the next few decades. As I look over my list, I see a great deal of overlap with these items and what is proposed in NSF's Global Geosciences Initiative and with some features of NASA's draft Earth Systems Science program and with the ideas for an international International Geosphere-Biosphere, or Global Change program. These overlaps are not coincidental, nor is the emphasis on a broader spectrum of necessary

disciplines. Rather, I believe that our experience of the last decade has proven that we must undertake much more research effort and sustain it if we wish to maintain a habitable planet for our present or higher human populations.

ATTACHMENT TO DR. RAMANATHAN'S STATEMENT

II. Background Text

1. Introduction

Increases in the planetary radiative heating induced by trace gases of anthropogenic origin is one of the dominant factors governing climate change on decadal to longer time scales. One particular example is the greenhouse effect of CO_2 increase which has been the subject of scientific curiosity since the latter half of the nineteenth century . Interest in the CO_2 problem gained tremendous momentum during the last two decades; this time period witnessed the development of a hierarchy of climate models with interactive clouds, oceans and cryosphere to examine the climate change that might result from CO_2 increase in the atmosphere. The last two decades also witnessed an unprecedented surge of interest in understanding the sensitivity of the ozone layer to chemical perturbations. The combination of these two developments gave rise to a series of scientific discoveries during the last decade.

First was the finding that the greenhouse effects of many polyatomic trace gases, e.g., the chlorofluorocarbons (CFCs) $CFCl_3$ and CF_2Cl_2, were greater than that of CO_2 increase on a molecule per molecule basis. Addition of one molecule of $CFCl_3$ (F11) or CF_2Cl_2 (F12) to the atmosphere was calculated to have the same surface warming effect as that due to an addition of 10^4 molecules of CO_2. Subsequently, it was uncovered that perturbations in stratospheric ozone can have perceptible effects on tropospheric climate through radiative-dynamical interactions between the stratosphere and troposphere. Furthermore, tropospheric ozone, which until recently was assumed to have negligible climate impact, was shown to be very effective in enhancing the greenhouse effect. Over the years, CH_4 and N_2O were added to the list of potentially important greenhouse gases, and the list is still growing. Finally, it has been estimated that the observed

increase in the concentration of CO_2, CH_4, CFCs and other trace gases, during the next several decades, can lead to a global surface warming that could surpass the observed temperature changes of the past century. In such estimates, the combined effect of increases in non-CO_2 trace gases was comparable to the greenhouse effect of CO_2 increase. The estimated effects on stratospheric climate were also substantial and far exceed the decadal scale natural variations.

These recent developments forced the scope of the problem dealing with the greenhouse theories of climate change to be broadened from the CO_2-climate problem to the trace gas-climate problem.

2. Climate Effects: Physical Principles

a. Trace gases and the Greenhouse effect

The so-called "greenhouse effect" of the atmosphere results from trace gases that are radiatively active, i.e., gases that absorb and emit infrared (or heat) radiation. The infrared (IR) radiation is contained between the wavelengths of 4 to 100μm (micrometers). The important naturally occurring radiatively active gases in the atmosphere are H_2O, CO_2, O_3, CH_4 and N_2O. Also present in the atmosphere are radiatively active gases that are solely due to industrial activities, e.g., CFC-11 ($CFCl_3$), CFC-12 (CF_2Cl_2), methyl chloroform (CH_3CCl_3). These gases absorb the IR radiation emitted by the warm surface of the earth and re-emit it to space at the much colder atmospheric temperatures. As a result, the net effect is a reduction in the energy emitted to space by the earth-atmosphere system. In other words, the radiatively active gases effectively trap the IR radiation within the surface-atmosphere system and this trapping of IR energy is what is known as the "greenhouse effect." The present day concentrations of H_2O, CO_2 and O_3 exert a significant greenhouse effect as documented dramatically by satellite measurements (Fig. 1). The pleasant living conditions on the planet depend crucially on this greenhouse effect. For example, without the greenhouse effect of the atmosphere, the planet, as a whole, would be so cold as to be virtually ice covered throughout the year.

b. Dirtying the atmospheric "window"

Reverting back to Fig. 1, we note that the maximum energy emitted to space is contained in the 8-13μm region. This is because, the unpolluted atmosphere is quite transparent in this region , except for ozone absorption in the 10μm region. As a result most of the radiation emitted by the

surface in the 8-13μm spectral region escapes to space. In fact, this is the primary spectral region through which the surface and the clouds ventilate heat to space. Because of this relative transparency, the 8-12μm spectral region is called the "atmospheric window." Many of the man-made pollutants, e.g. CFC-11 and-12, absorb very strongly in this window region and as a result they are extremely effective in enhancing the atmospheric greenhouse effect. For example, the addition of one molecule of CFC-11 and -12 can have the same greenhouse warming effect as adding 10,000 molecules of CO_2 to the atmosphere! Numerous trace gases that are emitted to the atmosphere by human activities have strong absorption bands in the window region as shown in Fig. 2. The absorption features of these gases have the effect of "dirtying" the atmospheric window.

C. The greenhouse effect, radiation budget and climate change

The fundamental energy source for the climate system is solar energy. The observed climate is due to a delicate balance between the absorbed solar energy and the IR energy emitted to space by the planet and these two terms constitute the radiation budget of the planet. On a long term (> 1 year) and on a global average basis, the budget is balanced, i.e., the absorbed solar energy is equal to the emitted IR energy. Now, when the concentrations of radiatively active trace gases increase, this radiation balance is disturbed because the gases trap more IR radiation in the system and cause a reduction of the IR energy emitted to space. In order to restore balance, the earth-atmosphere has to warm up and emit more IR energy. Thus the warming is based on this basic concept of global radiation budget.

D. Radiation budget and circulation of the atmosphere and oceans

Since the earth is a sphere, the planet receives significantly more solar energy in the

tropics than in the polar regions. The emitted IR energy is unable to completely offset the equator to pole gradient in the solar heating. Consequently there is a strong equator to pole gradient in the net radiative heating (absorbed solar energy minus IR emission) of the surface-atmosphere system. This heating gradient is the fundamental driving force for the atmospheric and oceanic general circulation patterns, including such major features as the jet stream, monsoonal circulation in the tropics and polar deep water circulation in the oceans. Altering the greenhouse effect through trace gas changes can alter the radiative heating gradients in a number of ways: the trapping of IR radiation itself is not uniform in all latitudes; a global scale warming induced by trace gases can melt sea-ice and snow cover which alters the absorbed solar radiations by the polar regions; a warmer ocean evaporates more moisture and the latent heat released in the atmosphere, in turn, alters the heating gradients.

e. Factors that govern decadal scale climate change

Various factors that govern climate change on decadal to longer time scales have been uncovered. Many of the factors fall under the category of externally (external to the climate system) induced variations in the climate forcing terms. The first set of factors involves global scale changes in the radiative heating such as due to: trace gases including CO_2, frequency of volcanic events and variations in solar insolation. Factors involving regional scale changes include changes in radiative forcing (turbidity, deforestation and desertification), thermal forcing (urban heat island) and thermodynamic forcing (alteration of evaporation and precipitation by deforestation is one example). Decadal scale climate change may also result from internal fluctuations in the interactions within the land-ocean-cryosphere-atmosphere system. Such internal flunctuations include variations in ocean heat storage, sea-ice and glaciers.

Of the various factors mentioned above, accurate determination of trends has been

possible only for CO_2 (at least since the 1950s), CH_4 and CFCs (since the 1970s). The greenhouse effect of CO_2 has received the most emphasis (in the literature) as a mechanism for climate change, and during the last few years attention is turning increasingly toward the other trace gases. For all other climate forcing terms, the measurements are either nonexistent or, when they exist, the accuracies are insufficient to determine decadal trends. The lack of measurements has prevented quantitative identification of the causal factors for the temperature trends of the last 125 years.

f. The trace gas-climate problem

Chemical pollutants in the atmosphere can modify the climate through one or more of the following processes:

(i) Radiative active gases: If the pollutants are radiatively active in the IR spectral region, they will enhance the atmospheric greenhouse effect. In particular, several polyatomic trace gases (of anthropogenic origin) have strong absorption features in the 7-13 μm region. In addition, perturbing gases such as CO_2 and O_3, which govern the magnitude of stratospheric IR emission and absorption, have significant impacts on stratospheric climate.

(ii) Chemically active gases: Gases such as CO and NO, which by themselves have negligible radiative effects, can alter the concentrations of radiatively active gases such as CH_4 and O_3 by chemical interactions.

(iii) Radiatively and chemically active gases: Gases such as CH_4 and CFCs are chemically active as well as radiatively active. Methane oxidation in the troposphere can lead to increased tropospheric O_3, and the effect of the O_3 decrease can either amplify or ameliorate the CFC greenhouse surface warming depending on the vertical distribution of the O_3 decrease.

(iv) Ozone change and stratosphere-troposphere radiative interactions: O_3 absorbs solar radiation in addition to absorbing and emitting IR radiation; hence, stratospheric O_3 modulates the solar and IR radiation reaching the troposphere. Stratospheric O_3 influences tropospheric climate through a complicated set of stratospheric-tropospheric radiative interactions in both the solar and IR radiation regimes. The greenhouse effect of tropospheric O_3 also plays a significant role in determining the sensitivity of climate to O_3 change. Consequently, it is very difficult to generalize the nature, the sign, and the magnitude of the potential climate change due to O_3 perturbations.

(v) Climate-chemistry interactions: The greenhouse warming of the surface causes an enhancement in the evaporation of moisture from the land and oceans resulting in an increase in the tropospheric H_2O. This, in turn, through photolysis and H_2O chemistry can perturb OH in the troposphere. Since OH plays a dominant role as a cleansing and oxidizing agent from tropospheric gases (including pollutants), the altered OH can potentially perturb the concentration of radiatively active species such as CH_4 and O_3 (and possibly others).

FIGURE CAPTIONS

Figure 1. The IR radiation measured over the tropical ocean from the NIMBUS 4 satellite. The dash curve indicates the black body emission. The 300 K curve is the black body emission by the surface of the ocean; if there was no intervening atmosphere, the satellite would have measured this curve instead of the solid curve shown in the figure. Hence the shaded region is the IR radiation trapped by the intervening atmosphere.

Figure 2. Spectral location of the absorption features of trace gases. λ is the wavelength in μm (micrometers); υ is wavenumber which is $(10{,}000/\lambda)$.

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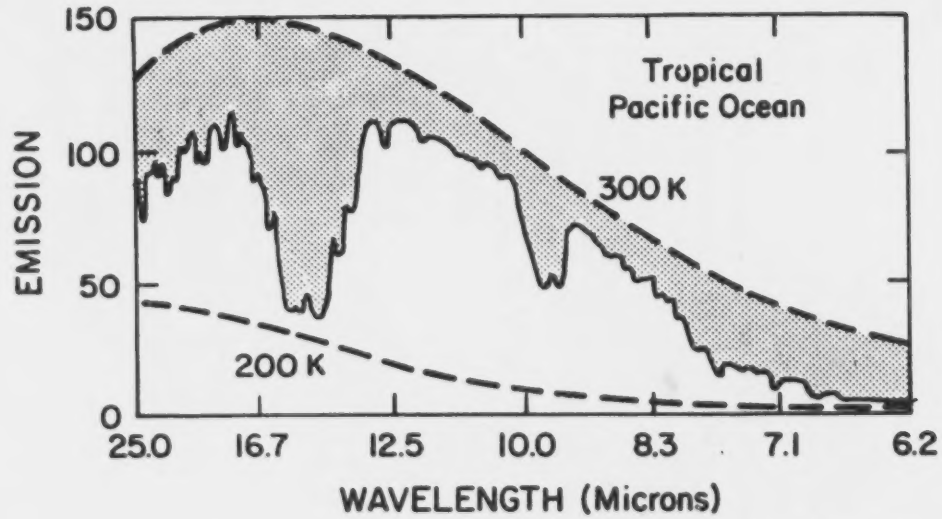

Source: Hanel at al. (1972)

OUTGOING LONGWAVE EMISSION
(NIMBUS 4 IRIS Measurement)

Figure 1

TRACE GASES WITH ABSORPTION IN THE ATMOSPHERIC "WINDOW"

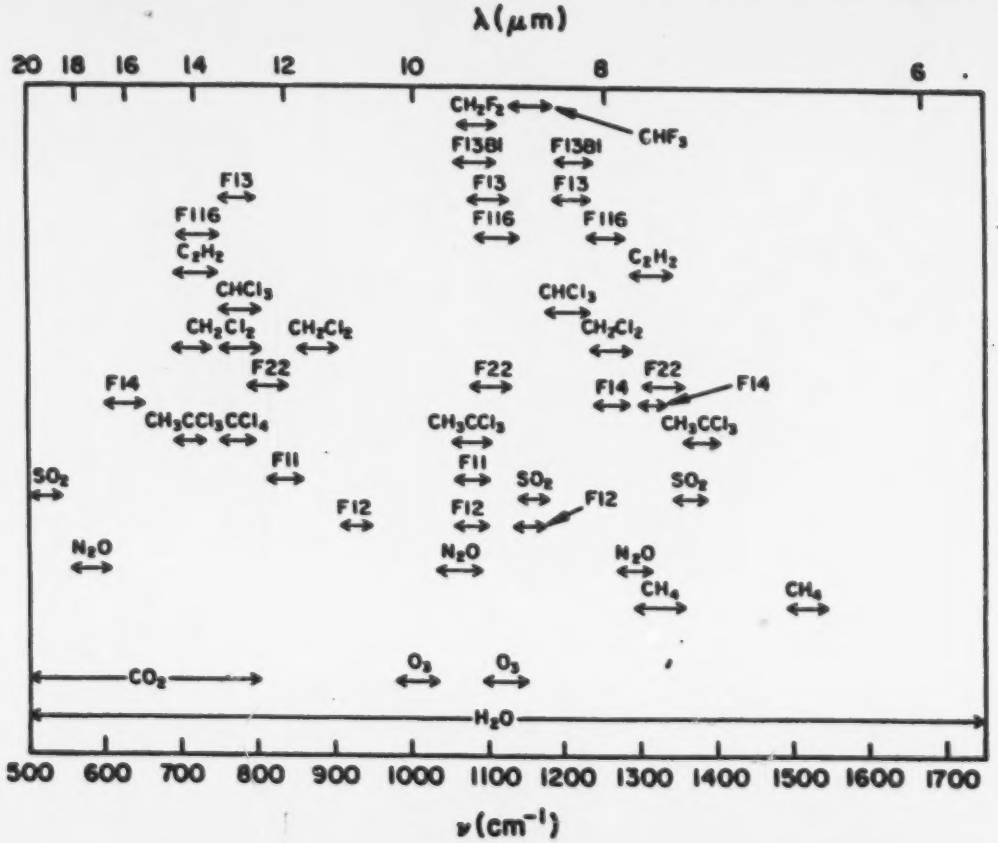

Figure 2

THE UNIVERSITY OF CHICAGO
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5734 S. ELLIS AVENUE
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February 23, 1987

Honorable Max S. Baucus and Honorable George S. Mitchell
United States Senators
Committee on Environment and Public Works
Washington D.C. 20510-6175

Dear Senators Baucus and Mitchell:

Thank you for your letter of January 30, 1987. I am very pleased to note the level of interest and concern reflected in your letter and in your questionaire. I am enclosing herewith my response to your questions.

First, I would like to make some remarks and then summarise my response to your questions. There are glaring gaps in our understanding of the global change induced by human activities. The progress on a national level is not as rapid as it could be, largely because no single research institution or government agency has come to grips with the problem. There is no national program to address the problem as a fundamental scientific investigation. However, some very favorable developments are beginning to happen.

(a) An inter-disciplinary and inter-agency committee, known as, the Earth System Science Committee (ESSC) has been set up under the chairmanship of Dr. Francis Bretherton and this committee has the tacit approval of the important research agencies to develop scientific strategies for addressing the global change issue;

(b) atmospheric scientists and oceanographers are, by and large, in agreement with regards to the overall research efforts needed to address the problem; and

(c) several national and international programs are either underway or are being planned to address some of the issues related to clouds and to coupled-ocean atmosphere modeling.

In order to exploit the momentum created by the above developments and significantly narrow the gap in our understanding of the human induced climate change, the following additional efforts are needed.

- Dedicated supercomputers for a) improved modeling of cloud formation in our

three-dimensional atmospheric models; and b) developing high-resolution coupled ocean-atmosphere models.

- A dedicated global climate observing system that in addition to maintaining the existing monitoring systems will incorporate a satellite based monitoring system with calibrated instruments to shed fundamental insights into how the climate system responds to external stimuli (such as trace gas increase) and how these stimuli are changing with time. The ESSC has prepared a list of the required measurements and I have given some details in the enclosed response

I should caution that the scientific programs of the sort I envision are quite ambitious and, even if implemented immediately, can yield the needed insights only on a time scale of about ten years. But, postponing our commitment to address the fundamental scientific issues will only worsen our current position of having to make policy decisions of global significance based solely on circumstantial evidence.

I am honored to participate in your deliberations and I am eager and happy to offer my assistance in any way possible. With best regards,

Yours sincerely,

V. Ramanathan

V. Ramanathan
Professor of Atmospheric Science

Response to Questions by Senator Mitchell

1) What other trace gases in addition to carbon dioxide, ozone, nitrous oxide, chlorofluorocarbons (CFCs), and methane do you expect to make a significant contribution to global warming?

The greenhouse effect of several other trace gases depend on their atmospheric concentrations. The current concentrations and the rate of increase of the following trace gases are such that they make only a small contribution. However, if their concentrations are allowed to exceed 1 ppb (part per billion), the following man-made gases can become significant.

F13 (CF_3Cl), F14 (CF_4), F22 ($CHClF_2$), F116 (C_2F_6), F13B1 (CF_3Br), CH_3CCl_3 (methyl chloroform), and CCl_4.

If the concentration of each of the above gases reaches 1 ppb, they can collectively have the same warming effect as that due to the observed increase in CO_2, CH4, CFCs and ozone from the pre-industrial era to the present.

2) Do you know the warming characteristics of CFC-113?

The warming characteristics are not known since the infrared absorption data is not available, at least in the open literature. Professor P. Varanasi at the State University of New York at Stony Brook will soon (within a month) be making these measurments. However, F-113, F-114, and F-115 have absorption in the so-called "atmospheric window" region of 8-13μm (micrometer) wavelengths and hence they have the potential for a strong greenhouse effect.

3) How large is the contribution of methane compared to carbon dioxide in terms of overall contribution to global warming?

The observed methane increase contributes about 20-30% of that due to the observed CO_2 increase.

4) In your written statment on page 3, you discuss the modeling uncertainty introduced by clouds. could you briefly explain what type and level of effort will be required to fill this gap in our climate understanding?

The outlook for a breakthrough in our understanding of the cloud problem, which looked very bleak until two years ago, looks quite promising now. The following developments have contributed to the ray of hope on the horizon.

• The multi-satellite earth radiation budget experiment (ERBE). ERBE was launched by the space shuttle in October 1984, and has yielded more than two years of continuous high quality data. The science team has come up with an innovative and remarkably simple procedure to extract the influence of clouds on the radiative heating of the planet (the enclosed figure shows a preliminary result).

• The international satellite cloud-climatology project (ISCCP). Current theories of cloud formation are relying on cloud cover data gathered before world war II. The ISCCP project, which was started last year, with its headquarters in the U.S., has started to process the data gathered by the weather satellites to map out the global distribution of cloud cover and the clear-sky brightness of the planet. These are two important pieces of information for climate models.

• Regional cloud experiments. Since 1986, U.S., Germany and Japan have initiated aircraft based experiments to gain insights into the processes that govern cloud formation.

The following additional efforts are needed to exploit the momentum created by the above developments so that we can examine the role of cloud-feedback in modulating the trace gas induced climate change.

• Continue the ERBE measurements for at least another 10 years beyond its current termination period of 1988. The data from this long term record will finally tell us whether clouds are heating or cooling the planet and the nature of the year to year variability in cloud effects

• The ISCCP project has a serious data gap because of the lack of data from the Indian

satellite (INSAT). Special bi-lateral negotiations may help secure the data from the Indian government.

• Calibration of the weather satelite instruments used by the ISCCP project. The data can then be used to provide fundamental understanding of how the brightness of the planet is changing under clear-sky and cloudy situations.

• Advanced laser instruments for satellite measurements of the global water vapor and precipitation distributions. Water vapor is the principal variable that governs climate and clouds and, yet, we do not have any global measurement of the H_20 distribution over much of the lower atmosphere.

• A dedicated supercomputer for modeling realistically the physical and dynamical processes of clouds in climate models.

5) The need for a dynamic coupled ocean-atmospheric model also was discussed at the hearing. How far are we in our efforts to develop such a model? What type and level of effort will be required?

I should caution that I am not an oceanographer. Ambitious steps are being undertaken at three national centers to develop coupled ocean-atmosphere models. The following steps will help the development of such models.

• U.S. participation in the world ocean circulaiton experiment, which amongst other things, will collect data on the vertical and horizontal distribution of passive tracers such as CFCs in the world oceans.

• A dedicated supercomputer for the development of high resolution coupled ocean-atmosphere models.

6) How worried are you personally about the magnitude of the changes which your models indicate are in store for the earth's climate?

I am very worried about the magnitude of the predicted changes. The principal reasons for my concerns are given below:

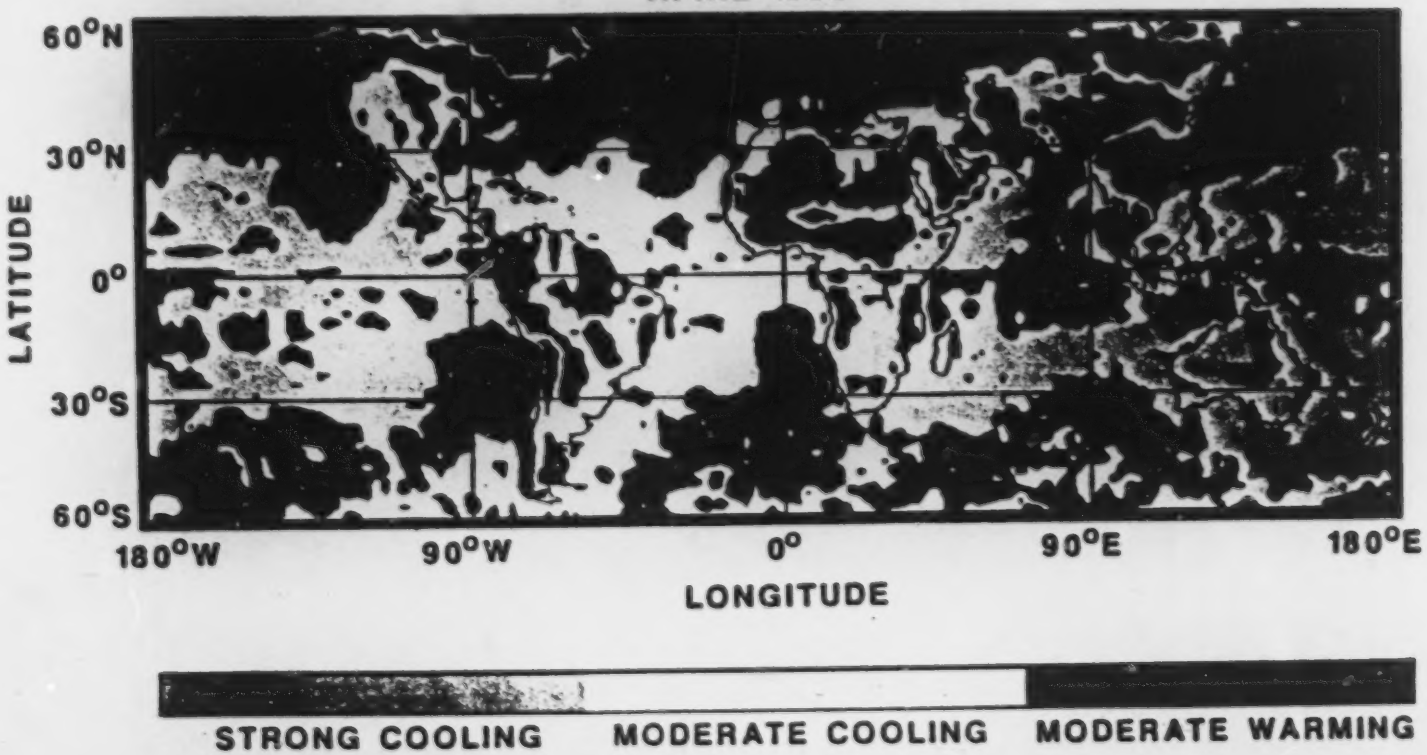
• The upper range of the predicted changes suggest that human activities have the potential for setting the climate system up in an unchartered course.

• We do not know even the qualitative, i.e. sign, nature of the cloud feedback and hence we can not rule out the possibility that the actual changes can be larger than the predicted changes.

• The predicted changes result from complex interactions between the chemical, physical and dynamical processes. With our present state of inadequate observational systems and theoretical understanding, we will be unable to "fingerprint" the trace gas induced climate changes until they become very large.

CLOUDS COOLING AND HEATING THE EARTH

AS OBSERVED BY THE NASA EARTH RADIATION BUDGET SATELLITE
APRIL 1985



Statement of

Ambassador John D. Negroponte,
Assistant Secretary of State
for
Oceans and International Environmental and Scientific Affairs
to the
Subcommittee on Toxic Substances and Environmental Oversight
Senate Committee on Environment and Public Works

January 28, 1987

The United States, along with other nations of the world, is engaged in an historic effort to undertake cooperative measures to prevent potentially serious adverse effects from depletion of stratospheric ozone. The Vienna Convention for the Protection of the Ozone Layer, signed in March 1985 under the auspices of the United Nations Environment Program (UNEP) and ratified by the United States in August 1986, was an important first step. But, as many of the members of this Committee noted in speaking in favor of ratification of the Convention, additional concrete measures are necessary. We are now engaged in negotiations under UNEP auspices on a protocol to the Convention which would provide for regulatory controls on ozone-depleting chemicals.

Laying the Foundation of Common Understanding of the Issue

Between the adoption of the Convention in Vienna in March 1985 and the resumption of negotiations on control measures in December 1986, the international community participated in a unique cooperative effort to improve common understanding of the nature and impacts of the ozone depletion issue. The United States Government played a leading role in that process.

-- A two-part UNEP workshop, in Rome in May 1986 and in Leesburg, Virginia in September 1986, focused on key economic issues related to the control of ozone-depleting chemicals.

-- In June 1986, the U.S. co-sponsored with UNEP an international conference with over 300 participants on the effects of both ozone depletion and climate change.

-- The Coordinating Committee on the Ozone Layer (CCOL), a UNEP body a comprising scientists from many interested nations, assessed current knowledge of the atmospheric science and effects of ozone depletion, and presented their findings to UNEP for consideration in the development of measures to protect the ozone layer. Scientists and policymakers from EPA and NASA played a leading role.

-- 150 scientists, coordinated by Dr. Robert Watson of NASA, prepared a landmark publication on the state of knowledge about atmospheric ozone, under the auspices of NASA, the World Meteorological Organization (WMO), UNEP, the European Communities, NOAA, FAA and the German Federal Ministry for Research and Technology.

At the same time, U.S. government representatives were working bilaterally with various governments to improve understanding of the nature of the problem and the options for reducing risks.

-- EPA, NASA and NOAA have worked with scientists in key nations, such as India, Egypt and Australia, to increase understanding of the risks if depletion should occur and to advance scientific assessment and monitoring capabilities.

-- We have discussed the issue with policymakers in key countries. For example, my Deputy Richard Benedick, who is the lead U.S. negotiator, and a team from EPA went to Brussels and Bonn last November for consultations in preparation for the December negotiations.

As this extensive bilateral and multilateral effort moved forward, we saw that consensus was emerging, both in the United States and in the international community, in a number of important areas:

-- The ozone layer is an exceedingly valuable resource for the present and future population of the world.

-- The ozone layer has been, is being, and will continue to be adversely affected by the long-lived chlorine molecules which stem from chlorofluorocarbons.

-- This ozone depletion, by permitting greater quantities of harmful ultra-violet radiation to reach the earth, will pose significant, even if currently difficult to quantify, risks.

-- These risks are sufficiently serious as to warrant control actions.

-- The very nature of the ozone layer requires global cooperation if protective measures are to be effective.

The U.S. Position

The United States Government believes that the potential risks to the stratospheric ozone layer require early and concerted action by the international community. We seek agreement on the following broad objectives:

- o A meaningful near-term first step to reduce significantly the risk of stratospheric ozone depletion and associated environmental and human health impacts;
- o A long-term strategy and goals for coping with the problem successfully; and
- o A carefully-scheduled plan for achieving the long-term goals, including periodic reassessment and appropriate modification of the strategy and goals in response to new scientific, technical and economic information.

We believe a protocol to achieve these objectives should:

- -- provide a simple approach to facilitate agreement within the current UNEP timetable;
- -- provide as much certainty as possible for industrial planning in order to minimize the costs of adjustment;
- -- provide adequate time for shifting away from ozone-depleting chemicals to avoid social and economic disruption, while at the same time give a strong incentive for the rapid development and employment of safer substitutes and recycling techniques;
- -- address CFC's 11, 12, and 113, and Halon 1211 and 1301, so that all the principal man-made sources of long-lived atmospheric chlorine and bromine are included;
- -- allow flexibility for national implementation by allowing trade-offs among controlled chemicals based on their relative ozone-depleting effects;
- -- take into full consideration scientific uncertainties and promote future improvements in understanding by instituting a requirement for periodic reassessment of the goal and timing of limits;
- -- create incentives to participate in the protocol by regulating relevant trade between parties and non-parties.

In response to UNEP's invitation, the United States prepared a draft text for the operative articles of the protocol which we believe offers a straightforward, cost-effective approach that will provide incentives and clear targets to governments and industry for developing and introducing new technologies for chemical conservation, recycling and substitution. The U.S. draft protocol text is attached.

Geneva, December 1986

We have come a long way since March 1985 in Vienna. In the first round of resumed negotiations in Geneva last month, representatives from all regions agreed that new measures must be taken in the near term to control emissions of ozone depleting chemicals. However, differences over the scope, stringency and time-phasing of control measures remain.

The week-long session included some 120 participants from 25 governments plus international organizations, industry and environmental groups.

The U.S. delegation focused in the first round on seeking support for the basic elements of a protocol which would have both meaningful near and longer term control measures; would cover a broad spectrum of ozone depleting chemicals; and would contain good scientific assessment and technology incentives.

Country Positions

Canada firmly supports a strong agreement. Canada has presented a draft providing for a global emissions limit (a) allocated nationally on the basis of gross national product and population and (b) measured in terms of adjusted production (production plus imports minus exports to parties). However, in the first negotiating session, the Canadians, like the U.S., sought to achieve consensus on the broad outlines of a protocol rather than on specific formulas.

The European Communities (EC) have moved from insistence on a production capacity cap (their current capacity is approximately 30% above current production) to consideration of a cap on production itself. Representatives of the EC Commission distributed at Geneva a "provisional paper" proposing that production of CFC 11 and 12 (and possibly 113 and 114) be frozen at 1986 levels and that the controls be reviewed periodically (i.e., further steps might be decided in the future, but would not be included in the protocol at this time).

Finland, Norway and Sweden endorsed the U.S. approach in general, and tabled an amendment to the U.S. text calling for a first step phase-down of 25 percent rather than a freeze.

While the USSR delegation acknowledged the risk of ozone depletion and the need for control measures, they introduced a text calling for a global production limit for CFC 11 and 12 only, allocated to nations on the basis of population, with less developed countries exempt from controls.

Japan, too, acknowledged the need for controls, but favored a production capacity cap, only on CFC 11 and 12.

Developing country representation at Geneva was sparse. Argentina, Brazil and Egypt participated actively in support of an early agreement.

Looking Ahead

The United States will continue in the next round of negotiations, February 23-27, to pursue the objectives outlined above. We are consulting actively with a number of nations in the interim, through discussions with environmental, foreign ministry, and trade officials in Washington and abroad, through our Embassies, official visits, and scientific exchanges.

Ambassador Benedick will leave in the next few days for consultations in Europe. Deputy U.S. Trade Representative Michael Smith discussed the issue with Japanese trade officials in Tokyo this week, and I will discuss it with Foreign Ministry and environmental policy officials in Tokyo next week. A team from NASA, NOAA and EPA will visit the Soviet Union February 3-9 to exchange information on the chemistry and dynamics of the atmosphere as it relates to ozone depletion and on the effects of increased ultraviolet radiation. We are meeting this week with Canadian representatives. Yesterday, through the USIA "Worldnet" interactive satellite hookup, Ambassador Benedick and Dr. Watson of NASA discussed the issue with experts, policymakers and journalists in London, Rome, Copenhagen, Paris and Geneva; another such program is planned for next month with several other capitals.

This is a difficult and complex negotiating process. We have made substantial progress, but we have a long way to go to reach an effective agreement with broad participation. Meanwhile, we must be sure that our actions domestically support and do not undercut that international process, since this is clearly a matter which the U.S. cannot resolve alone. We have entered a new era of truly global environmental management, in which we are all made more conscious of the unity and vulnerability of our planet.

United States Proposed Protocol Text

UNEP Negotiations on an Ozone Layer Protocol

December 1-5, 1986
Geneva, Switzerland

The United States believes that the potential risks to the stratospheric ozone layer from certain man-made chemicals require early and concerted action by the international community. Since the adoption in Vienna in March 1985 of the Ozone Layer Convention, an intensive scientific research and technical analysis effort has been carried out and is continuing, as reflected in the recent series of UNEP-Sponsored workshops. The results continue to indicate the emergence of a serious environmental problem of global proportions.

The United States further believes that governments should pursue three broad objectives during the course of the negotiations, to be embodied and elaborated in the final protocol. These are:

A. Agreement on a meaningful near-term first step to reduce significantly the risk of stratospheric ozone depletion and associated environmental and human health impacts.

B. Agreement on a long-term strategy and goals for coping with the problem successfully.

C. Agreement on a carefully-scheduled plan for achieving the long-term goals, including periodic reassessment and appropriate modification of the strategy and goals in response to new scientific and economic information.

In response to UNEP's invitation, the U.S. has prepared for discussion purposes a draft text based on the U.S views statement which we recently circulated. This text is for the operative articles only, and is designed for incorporation into the protocol text developed during the previous round of negotiations (i.e., it would replace Articles II through V of the fourth revised draft text).

The United States believes that what is required is a straightforward, cost-effective approach that will provide technology incentives and clear targets to governments and industry for developing and introducing new technologies for chemical conservation, recycling and substitution. The U.S. believes that its proposed text provides such an approach.

U.S. DRAFT PROTOCOL TEXT: OPERATIVE ARTICLES

Article II: Control Measures

1. Within [ ] year after entry into force of this Protocol, each Party shall ensure that its aggregate annual emissions of fully-halogenated alkanes does not exceed its 1986 level.

2. Within [ ] years after entry into force of this Protocol, each Party shall ensure that its aggregate annual emissions of fully-halogenated alkanes is reduced by [20] percent from its 1986 level.

3. Within [ ] years after entry into force of this Protocol, each Party shall ensure that its aggregate annual emissions of fully-halogenated alkanes is reduced by [50] percent from its 1986 level.

4. Within [ ] years after entry into force of this Protocol, each Party shall ensure that its aggregate annual emissions of fully-halogenated alkanes is reduced by [95] percent from its 1986 level.

5. The right of any Party to adopt control measures more stringent than contained herein is not restricted by this Article.

Article III: Calculation of Aggregate Annual Emissions

1. For the purposes of Article II, each Party shall calculate its aggregate annual emissions by taking its:

   a. aggregate annual production;

   [b. plus aggregate annual bulk imports;]

   [c. minus aggregate annual bulk exports to other Parties;]

   [d. minus aggregate annual amount of fully-halogenated alkanes which have been destroyed or permanently encapsulated.]

2. To calculate the aggregate amounts specified in the sub-paragraphs of paragraph 1, each Party shall multiply the amount of each fully-halogenated alkane by its ozone depletion weight, as specified in Annex A, and then add the products.

Article IV: Assessment and Adjustment of Control Measures

1. The Parties shall cooperate in establishing an international monitoring network for detecting, or aiding in the prediction of, modification of the ozone layer.

2. At least one year before implementing the reductions specified in paragraphs 2, 3, and 4, respectively, of Article II, the Parties shall convene an ad hoc panel of scientific experts, with composition and terms of reference determined by the Parties, to review advances in scientific understanding of modification of the ozone layer and the potential health, environmental, and climatic effects of such modification.

3. In light of such scientific review, the Parties shall jointly assess and may adjust the stringency, timing, and scope of the control measures in Article II and the ozone depletion weights in Annex A.

4. Any such adjustment shall be made by amending Article II and/or Annex A as provided in Article 9 of the Convention, except that such amendment would not be subject to the six month advance notice requirement of paragraph 2 of that Article.

Article V: Control of Trade

1. Within [ ] years after entry into force of this Protocol, each Party shall ban the import of fully-halogenated alkanes in bulk from any state not party to this Protocol [, unless such state is in full compliance with Article II and this Article and has submitted information to that effect as specified in paragraph 1 of Article VI].

2. Within [ ] years after entry into force of this Protocol, each Party shall ban:
   a. the export of technologies to the territory of non-parties
   [b. direct investment in facilities in the territory of non-parties]

   for producing fully-halogenated alkanes [, unless such state is in full compliance with Article II and this Article and has submitted information to that effect as specified in paragraph 1 of Article VI].

3. The Parties shall jointly study the feasibility of restricting imports of products containing or produced with fully-halogenated alkanes from any state not party to this Protocol.

Article VI: Reporting of Information

1. Each Party shall submit annually to the Secretariat data showing its calculation of aggregate annual emissions of fully-halogenated alkanes, as specified in Article III, using the format developed by the Secretariat pursuant to paragraph 3a.

2. Each Party shall submit to the Secretariat appropriate information to indicate its compliance with Article V.

3. The Secretariat shall:

   a. develop and distribute to all Parties a standard format for reporting such data as indicated by paragraph 1;

   b. take appropriate measures to ensure the confidentiality of all data submitted to it pursuant to paragraph 1, except for the aggregate annual emissions figures;

   c. compile and distribute annually to all Parties a report of the aggregate annual emissions figures and other information submitted to it pursuant to paragraph 2.

United States Department of State

Washington, D.C. 20520

Dear Senator Mitchell:

Thank you for your January 30 letter, signed also by Senator Baucus, with which you enclosed questions supplementary to Ambassador Negroponte's January 28 testimony before the Subcommittees on Environmental Protection and on Hazardous Wastes and Toxic Substances concerning international efforts to protect the stratospheric ozone layer.

The Department of State must rely on the responsible technical agencies for input on many aspects of an issue such as this. The enclosed responses were prepared in close coordination with the U.S. Environmental Protection Agency. These responses incorporate comments by the Department of Energy, the National Oceanographic and Atmospheric Administration, other parts of the Department of Commerce, the Department of Defense, and the Council on Environmental Quality.

I welcome your interest in this important and complex issue.

With best wishes,

Sincerely,

J. Edward Fox

J. Edward Fox
Assistant Secretary
Legislative and Intergovernmental Affairs

The Honorable
George J. Mitchell,
Chairman,
Subcommittee on Environmental Protection,
United States Senate.

SENATORS BAUCUS/MITCHELL QUESTIONS

Question 1: (a), (b), and (c)

What is the priority given to global warming and ozone depletion by the various offices within EPA? What activities, commitment of resources, budgets, and level of effort has been undertaken both currently and on a yearly basis since 1974?

Response

Within the past two years, these issues have quickly surfaced as priority items in the agendas within several EPA offices. The attached exhibits reflect the priority given to these issues: Exhibit 1 describes international initiatives taken by EPA and the State Department regarding stratospheric ozone negotiations; Exhibit 2 summarizes global warming and ozone depletion activities undertaken by the various offices within EPA; and Exhibit 3 presents the Agency's allocation of resources for these activities.

EPA published an ambitious schedule of activities in January 1986 as part of its Stratospheric Ozone Protection Plan. This program set forth a series of domestic and international workshops and conferences, stated our intent to actively pursue an international protocol, and called for a decision on the need for additional regulation by November 1987. In implementing that plan within the past year, EPA has sponsored or participated in four major domestic meetings and three international conferences, and participated in the resumption of negotiations on an international protocol last December. EPA has also published a five-volume draft risk assessment and a four-volume proceedings from the "effects" conference co-sponsored with UNEP.

EPA's climate research activities have also been expanded, with the establishment of an intra-agency working group, expansion of bilateral research activities on climate-related issues, and initiation of efforts to prepare two major studies as requested by other senators and yourselves last summer.

Because of the international aspect of the ozone depletion issue, working closely with the Department of State, EPA has particularly expanded its international efforts.

EXHIBIT 1

U.S. GOVERNMENT INTERNATIONAL INITIATIVES ON STRATOSPHERIC OZONE NEGOTIATIONS

In the period prior to the December 1-5 UNEP negotiations in Geneva, the United States Government, through a series of cables to U.S. Embassies in participating countries, through a mission in November to key European capitals headed by Deputy Assistant Secretary of State Benedick, and through press briefings here and abroad, attempted to set the stage for constructive international consideration and effective action on this complex issue. The following items include specific activities undertaken since the December meeting, as part of a concerted U.S. effort, looking toward the February 23-27 second round of negotiations in Vienna, to build international support for early conclusion of an effective protocol to protect the ozone layer from potentially harmful chemicals.

1. Ozone layer issue was raised by State Department and EPA during U.S.-Soviet bilateral environmental meeting in Washington, December 13-17, and agreement was obtained to hold early consultations on science of ozone depletion in Moscow (see item 12).

2. In early January, UNEP was urged, via telephone conversation with Executive Director Tolba and through the U.S. Permanent Representative in Nairobi, to adhere to the original February negotiating timetable, and to ensure greater participation in the negotiations by developing countries.

3. EPA Administrator Thomas called U.K. Environment Minister Waldegrave to seek his help in keeping to the negotiating schedule, and to explore ways of elevating the importance of the issue in Europe. Agreement was reached that early visits by a U.S. mission would be helpful (see item 11).

4. Cable was sent in January to European capitals asking the U.S. Mission in Brussels and U.S. Embassies in European Community (EC) member countries to approach European leadership to urge that EC representatives come to Vienna with sufficient negotiating flexibility. U.S. Ambassador to the EC Middendorf met with EC Commissioner.

5. Issue was placed on the agenda of U.S.-EC bilateral consultations scheduled for Washington in late March.

EXHIBIT 1 (continued)

U.S. GOVERNMENT INTERNATIONAL INITIATIVES ON STRATOSPHERIC OZONE NEGOTIATIONS

6. Assistant Secretary of State Negroponte and Deputy U.S. Trade Representative Smith discussed ozone protocol with senior Japanese officials during separate visits to Tokyo.

7. EPA Administrator Thomas raised the ozone issue in Washington with the Japanese Ambassador, which led to an invitation for a U.S. scientific team to visit Tokyo.

8. USIA "Worldnet" was utilized on January 27 and February 11 for interviews with Deputy Assistant Secretary of State Benedick (the head of the U.S. negotiating team) and NASA Senior Scientist Watson, involving reporters, scientists, and officials in London, Paris, Geneva, Rome, Oslo, Copenhagen, Bonn, Vienna, the Hague, and Ottawa. Response from participating countries was extremely positive: Vienna, for example, characterized the program as its "most successful Worldnet," and reported that long segments were telecast to millions of viewers in Austria, Hungary, and Czechoslovakia.

9. Consultations with a Canadian delegation held January 29 in Washington led to a coordinated approach to UNEP on structuring the February agenda.

10. Ambassadors Negroponte and Benedick discussed ozone layer issue with Brazilian Minister of Environment.

11. On February 2-4 Deputy Assistant Secretary Benedick led a mission, which included representatives of EPA and NASA, to Brussels, Paris, and London for cabinet-level meetings with governments and with the European Commission, and for scientific discussions.

12. A scientific team, led by NASA's Watson, and including representatives from EPA, NOAA, and a prominent Norwegian researcher, was sent to Moscow for consultations February 3-7.

13. Benedick press conferences on ozone held in Paris and Brussels included representatives from Le Monde, Figaro, Reuters, and others. Brussels Le Soir featured the ozone issue on page one of its February 3 edition; Newsweek will run a cover story on ozone in its European edition.

EXHIBIT 1 (continued)

U.S. GOVERNMENT INTERNATIONAL INITIATIVES ON STRATOSPHERIC OZONE NEGOTIATIONS

14. Nordic nations and Canada attended meetings on the ozone issue which were held in Geneva February 4-6 by the EPA representative to the EEC Working Group on Nitrogen Oxide Protocol.

15. Secretary of State Shultz raised the ozone issue with Belgian Foreign Minister Tindemans during consultations in Washington. (Belgium currently holds the EC Presidency.)

16. A cable sent February 10 to U.S. Embassies in numerous industrialized and developing countries further explained the U.S. position and solicited support.

17. Deputy Secretary of State Whitehead and EPA Administrator Thomas, in separate meetings February 17 and 18 with UNEP Executive Director Tolba, emphasized the importance that the U.S. attaches to successful negotiation of a strong ozone protocol, and to Tolba's personal involvement in the process.

18. On February 19, Ambassador Benedick appeared on USIA's "America Today," which is telecast to millions of viewers in Western Europe. He also held a press conference on the ozone negotiations at the State Department for U.S. and foreign correspondents.

EXHIBIT 2

SUMMARY OF GLOBAL WARMING AND OZONE DEPLETION ACTIVITIES WITHIN EPA OFFICES

Office	Global Warming Activities	Ozone Depletion Activities
Office of Air and Radiation	Policy analysis	Policy analysis, regulation development, International protocol development
Office of Policy, Planning and Evaluation	Policy and economic analysis	Policy and economic analysis Regulatory review and analysis
Office of International Activities	Management of international activities	International protocol development
Office of Research and Development	Scientific assessment, regional analyses and effects research	Characterization and effects research

EXHIBIT 3

AGENCY RESOURCES DEDICATED TO STRATOSPHERIC OZONE DEPLETION AND GLOBAL WARMING 1974-1988
(thousands of dollars)

Office	Year 1988	1987 a/	1986	1985	1984	1983	1982
OAR							
Ozone:	0 5 FTE b/	3,000 6 FTE	813 2.5 FTE	NOTHING FOR PROGRAMS BEFORE 1986			
Climate:	0	0 1 FTE	0				
OPPE							
Ozone:	500	500 3.5 FTE	500 3 FTE	350 2 FTE	0 1 FTE	0	
Climate:	400 7 FTE	2,600 5.5 FTE	735.1 3.5 FTE	433. 3 FTE	487.5 4 FTE	??? ?1 FTE	
ORD							
Ozone:	874.1 1 FTE	856.9 1 FTE	721.2 0 FTE	699.8 2.1 FTE	689.4 1.8 FTE	736.7 2 FTE	765.6 1.3 FTE
Climate:	2,000 3 FTE	2 FTE		NO CLIMATE ALLOCATIONS PRIOR TO 1986			
Reprogram: (climate only)		1 FTE 1,000					
ORD TOTAL	2,874.1 4 FTE	1,856.9 c/ 4 FTE					
OIA	ALL NUMBERS ARE APPROXIMATE 1.2 FTE (No Budget)	1.2 FTE	.5 FTE (Approximately 1 staffer, part-time)	.5 FTE	.5 FTE	.5 FTE	
OTS					1984 PROGRAM TRANSFERRED FROM OTS (approximately 1-2 FTE)		200

EXHIBIT 3 (continued)

AGENCY RESOURCES DEDICATED TO STRATOSPHERIC OZONE DEPLETION AND GLOBAL WARMING 1974-1988
(thousands of dollars)

Office	Year 1981	1980	1979	1978	1977	1976	1975	1974
OAR								
OPPE (includes climate)								
ORD Ozone:	1215.1 2.2 FTE	1260.8 0.8 FTE	NO NUMBERS AVAILABLE PRIOR TO 1980					
OIA								
	ALL NUMBERS ARE APPROXIMATE					TSCA PASSED IN 1976 NO EFFORT PRIOR		
OTS	4 FTE (AMPR)	4 FTE	2 FTE	2 FTE	2 FTE			

a/ 1987 figures include Congressional add-on: Agency total of $5 million (2M for climate, 3M for ozone) and 11 full-time employees (5 FTEs for climate, 6 FTEs for ozone)

b/ FTE = Full-time Employee

c/ In addition, in FY87 $1.5 million in extramural funds are appropriated for long-term research on stratospheric modification and climate.

Question 2

It is my understanding that the Agency's analysis indicates that CFC emissions must be reduced by about 85 percent to maintain the existing levels of ozone in the stratosphere. What is the relationship between the different production scenarios and their effect on depletion of ozone?

(1) a production capacity cap and a worldwide ban on aerosols

(2) all of (1) plus an immediate freeze on CFC-11 and CFC-12

(3) all of above, expanding the freeze to include CFC-113

(4) all of above plus a 10% reduction in ozone-depletion capacity

(5) all of above plus a 20% reduction in ozone-depletion capacity

(6) all of above plus a 50% reduction in ozone-depletion capacity

(7) all of above plus a 70% reduction in ozone-depletion capacity

(8) all of above plus a 85% reduction in ozone-depletion capacity

(9) all of above plus a 95% reduction in ozone-depletion capacity

(10) all of above plus complete phase-out

Response

Estimates based on current models of ozone depletion over time have been prepared for the ten scenarios of controls outlined in the question. These estimates of ozone depletion are subject to a variety of uncertainties and further model development is an on-going process. For a given set of assumptions, atmospheric models differ by a factor of about two. Additionally, there is significant uncertainty regarding which set of assumptions to use about the future. Consequently, in evaluating the level of protection provided by the set of controls defined above, one must be aware that the level of depletion that may actually occur may be larger or smaller than the level reported by models because: (1) the models may be incorrect; or (2) the assumptions used in the models may be incorrect.

The model used to evaluate potential depletion is a statistical representation of a 1-dimensional model developed at Lawrence Livermore National Laboratories. This model was also used to prepare EPA's draft risk assessment document currently being reviewed by EPA's Science Advisory Board.

Exhibit 4 displays the major assumption used to evaluate the control scenarios. The key assumptions include:

EXHIBIT 4

ASSUMPTIONS USED TO EVALUATE OZONE DEPLETION

1. World Production and Production Capacity in 1985 (millions of kilograms)

Compound	Production	Production Capacity
CFC-11/12	850	1,240
CFC-22	111	162
CFC-113	163	238
CC14 (Carbon tet)	71	104
CH3CC13	545	795
Halon-1211	11	16
Halon-1301	11	16

2. Rate of growth of the use of these compounds in the absence of controls is 2.5 percent per year through 2050, with no growth thereafter.

3. The controls become effective on 1990.

4. There is 80 percent compliance.

5. Other trace gas concentrations grow as follows:

   -- Carbon dioxide: 50th percentile estimate from the 1983 NAS report Changing Climate (approximately 0.5 percent per year).

   -- Methane: 0.017 ppm per year (approximately 1 percent of current concentrations).

   -- Nitrous Oxide; 0.2 percent per year.

6. Reductions in ozone-depleting potential are modeled by across-the-board reductions in all the compounds.

7. Aerosol use of CFC-11 and CFC-12 is approximately 25 percent of current use.

- Production Capacity: the production capacity cap (control scenario 1) was assumed to apply to all potential ozone-depleting substances. The levels of current production capacity worldwide for the different chemicals are subject to uncertainty. The levels used for each chemical are listed in Exhibit 4.

- Aerosol Ban: the portion of CFC-11 and CFC-12 use going to aerosol propellant applications is estimated at about 25 percent.

- Reductions in Ozone-Depletion Capacity: these reductions were modeled by assuming across-the-board reductions in all ozone-depleting substances. Similar reductions in ozone-depleting potential can be achieved by larger reductions in a smaller group of substances.

- Timing: the controls are assumed to take effect in 1990.

- Compliance: the level of global compliance is assumed to be 80 percent. This assumption implies that 20 percent of the baseline use of the substances remains unaffected by the control scenario. Alternative assumptions regarding compliance are possible, and 80 percent is chosen to be illustrative.

- Other trace gases: the potential future growth in the atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have a large influence on estimates of future ozone depletion. The assumptions listed in Exhibit 1 are considered to be "best estimates" at this time based on relatively short periods of observations. However, if actions are taken by governments to limit the growth in these concentrations in order to limit the potential for global warming (these gases are also greenhouse gases), then the rates of growth for these concentrations used in this analysis will be too high, and the actual ozone depletion that will occur will be higher. The sensitivity of the estimates to the trace gas assumption is presented below.

Based on these assumption, global average ozone depletion was estimated for the ten control scenarios defined above. Of note is that ozone depletion is expected to vary by latitude, with depletion being greater than the world average at latitudes above approximately 40 degrees north. Consequently, even when the global average ozone depletion is small (or when ozone is estimated to increase in abundance), the level of ozone depletion at populous northern latitudes may be significant. Models capable of evaluating these latitudinal differences are currently under development.

Exhibit 5 displays the ozone depletion estimates for the years 2000, 2025, 2050, and 2075. The base year, 1985, is assumed to have no depletion (i.e., 0.0 percent). All ten control scenarios result in estimates of depletion by the year 2000. Depending on the stringency of the controls, the estimates for the later years may be depletion or increased abundance of ozone (listed as negative depletion in Exhibit 5).

The sensitivity of the estimates to the assumed growth in other trace gases is shown in Exhibit 5 for cases 8A, 9A, and 10A. Under these scenarios the same controls are applied as in scenarios 8, 9, and 10. However, the concentrations of carbon dioxide, methane, and nitrous oxide are assumed to stop growing in the year 2000. The resulting estimates of ozone depletion are listed.

EXHIBIT 5

ESTIMATES OF GLOBAL OZONE DEPLETION*
(percent)

Control Scenario	Year 2000	2025	2050	2075
1	0.7	2.0	3.7	5.5
2	0.6	1.4	2.3	3.3
3	0.6	1.3	2.2	3.1
4	0.5	0.9	1.3	2.2
5	0.5	0.7	1.2	1.8
6	0.4	0.2	0.3	0.7
7	0.3	-0.1	-0.2	0.0
8	0.2	-0.3	-0.6	-0.5
8A	0.2	0.8	1.9	3.5
9	0.2	-0.5	-0.8	-0.8
9A	0.2	0.6	1.6	3.1
10	0.1	-0.6	-0.9	-1.0
10A	0.1	0.5	1.5	2.9

* See text for assumptions. Positive numbers are ozone depletion. Negative numbers are increases in ozone abundance. Cases 8A, 9A and 10A assume no increase in trace gas concentration beyond the year 2000 (CO_2, CH_4, and N_2O).

Question 3: (a), (b) and (c)

(a) What products containing, or made with, CFCs are involved in international commerce?

(b) Which of these products are exported, imported?

(c) What percentage of these products are consumed in the United States?

Response

A wide variety of industrial and consumer products are manufactured with CFCs or contain CFCs. Exhibit 6 lists these products, virtually all of which are exported from or imported to the United States to some degree. Data are currently being collected on the levels of these imports and exports. The attached memorandum to the Office of Environment & Health presents data collected to date by the International Trade Administration of the Department of Commerce.

EXHIBIT 6

PRODUCTS MANUFACTURED WITH OR CONTAINING CFCS

Product	Role of CFCs	Comments
Aerosol Products	Propellant	Aerosol propellants are banned in the U.S., including imports and exports, for nonessential applications.
Rigid Foam	Used in manufacture. CFCs remain in the foam.	Believed to not be traded extensively in bulk form. Traded as parts of products that contain the foams, such as refrigerators, packaging material, and furniture.
Flexible Foam	Used in manufacture. CFCs do not remain in the foam.	Believed to not be traded extensively in bulk form. Traded as parts of products that contain the foam, such as furniture and automobiles.
Refrigeration and Air Conditioning	CFCs are the working fluid within the equipment (sometimes referred to as refrigerant).	Refrigeration and air conditioning equipment is traded internationally. Parts for this equipment are also traded.
Electronic Equipment and Capital Goods	CFCs are used as solvents to clean electronic components and metal parts during their manufacture. The CFCs do not remain in or on the products.	A very wide range of products--from computers to automobiles--contain components that can be cleaned with CFCs. The trade volume of this full range of products is very large. Not all manufacturers use CFCs across all applications.

70-303 0 - 87 - 6

UNITED STATES DEPARTMENT OF COMMERCE
International Trade Administration
Washington, D.C. 20230

-34-

JAN - 9 1987

MEMORANDUM FOR: Suzanne Butcher
Office of Environment and Health
Department of State (OES/ENH)

FROM: Michael J. Kelly
Acting Director
Office of Chemicals and Allied Products

SUBJECT: CFC Protocol: Products

As you requested, we have reviewed trade data on imports and export of products made with or containing chlorofluorocarbons. Three product areas of potential interest emerged and were considered: airconditioning and refrigeration equipment, polyurethane foam products, and electronic circuit boards.

Airconditioning and Refrigeration Equipment - - 5 M lbs.

Airconditioning and refrigeration equipment enter this country as stand-alone units, and as components of automobiles and trucks.

Generally, airconditioners with a capacity below 17,000 BTU per hour are charged with Freon 22 in the country of origin. Because these imports contain Freon 22, they are not of concern.

Imports of airconditioners above this capacity are generally charged with Freon 12 in the receiving country. In 1986 about 2,500 units were imported. Each of these units requires about 2 1/2 pounds of charge. (Airconditioning condensing units and airconditioners NSPF constituted 500,000 units in 1986.) Because these units are charged domestically, there is no "leverage" in considering these commodities as candidates for import restriction.

In 1985 we imported 2.816 million automobiles, 53.7 percent equipped with airconditioners. Each automobile airconditioner is charged with about 2 1/2 pounds of Freon 12 in the country of production. Thus 3.78 million pounds of CFC entered the U.S. via this route

1985 imports of light trucks were 769,000 units, 18.2 percent equipped with A/C (140,000 airconditioners). Again, each airconditioner is charged with 2 1/2 pounds of Freon. This equates to 350,000 pounds of CFC entering the U.S.

To summarize the concern about airconditioners: about 4.1 million pounds of Freon 12 enters the U.S. annually with airconditioning equipment.

Approximately 1,500,000 refrigerators and freezers were imported in 1986. Each unit contains about 0.7 pounds of Freon 12 as a charge. Potentially releaseable CFCs imported with refrigerators and freezers amounts to about 1 million pounds.

Polyurethane Foam Products - - None

Imported automobiles contain CFC produced rigid and flexible polyurethane foam. The rigid foam (e.g., dashboards) does not release the CFCs because of its closed-cell structure. The flexible foam (e.g., seats) is open-cell foam which releases the CFCs within thirty days. Any CFC concern in this area should be attributed to the country of production.

Refrigerators and freezers also contain about 1 1/2 pounds of Freon 11 and 12 captured in rigid insulating foam. The rigid foam does not release captured CFCs (see above).

FOAM IN UPHOLSTERED FURNITURE DATA MISSING

Whatever the figures, this foam is flexible, open-cell, and any contained CFCs are released within thirty days. Any emission will almost certainly occur in the country of production.

Electronic Equipment

CFC 113 is used in all phases of production of electronic equipment as a cleaning agent. Because CFC is relatively expensive, the cleaning process used is a closed system, and recovery rate of CFC 113 is greater than 99 percent. World production data for CFC 113 is not readily available. Any concern on CFC 113 emissions for this application should be attributed as a problem to the country of production.

Question 4 (a), (b), (c), and (d)

Considering the task confronting UNEP and the resolve of the U.S. to rely upon international cooperation -- both for measures related to global warming and to protect the stratosphere --

(a) What level of funding is required to undertake this effort?

(b) Does UNEP have adequate funding to carry on this effort?

(c) What has been the level of U.S. funding over the past 15 years?

(d) For each year, what percentage of UNEP's budget has been supplied by the U.S.?

Response

(a) UNEP's primary role is to recommend initiatives, carry out negotiations, and encourage operating UN bodies and governments to carry out necessary work in an effective, coordinated fashion. UNEP's Global Environmental Monitoring System (GEMS) is in a position to play a key role by identifying, assisting in the collection of, and analyzing data on the upper atmosphere and climate, as well as data on health and ecological impacts. UNEP must enlist others to do the actual collection and modelling, and other related tasks.

Total funding requirements are difficult to determine because UNEP enlists outside support for most of the work related to "this effort." The amount of funding required for the ozone negotiations is not large: staff time for 2-3 individuals, plus conference costs, which includes travel support for participants from developing countries. (EPA has provided supplemental funding to UNEP to assist in attracting key Third World officials to ozone workshops and the negotiations.)

(b) UNEP has adequate funding and staff resources. It is a matter of establishing ozone and climate as priority issues, and allocating resources accordingly (which the UNEP Executive Director has flexibility/authority to do). The U.S. has strongly advocated to UNEP officials that they keep examining these resource commitments.

(c) and (d) Exhibit 7, below, shows UNEP funding since 1973 and the percentage contributed by the U.S.

EXHIBIT 7

UNEP FUNDING LEVELS
(millions of U.S. dollars)

Year[1]	Total Contributions[2]	U.S. Contribution	U.S. Percentage of UNEP Total
1973	11.8	4.3	36
1974	20.5	5.0	24
1975	14.2	3.2	23
1976	23.4	7.5	32
1977	28.7	10.0	35
1978	29.3	10.0	34
1979	32.1	10.0	31
1980	31.6	10.0	32
1981	30.8	10.0	32
1982	29.4	7.9	27
1983	28.9	7.8	27
1984	28.6	10.0	34
1985	28.6	10.0	35
1986	29.8	8.6	28.9
1987[3]	30.3	6.8	22.7

[1] UNEP was established in 1972.

[2] In addition to these voluntary contributions, UNEP receives an administrative budget of $5-6 million per year from the UN assessed budget (of which the U.S. contributes 25%).

[3] Numbers are preliminary estimates.

Question 5: (a) and (b)

During the last Congress, $5 million, in addition to existing appropriation levels, was appropriated for research on global warming and ozone depletion, as part of the continuing resolution.

(a) How has this additional appropriation been utilized?

(b) What projects are planned and when will these funds be expended?

Response

(a) and (b) For FY 1987 the Congress appropriated $5 million, above the Administration's request, to support activities related to research on and response to global warming and stratospheric ozone depletion. Of the $5 million, $2 million was allocated for activities related to global warming and $3.0 million, for ozone depletion. In addition, Congress also appropriated an additional $1.5 million for long-term research on stratospheric ozone and climate change. The Agency intends to use the funds for these activities and to obligate the funds during FY 1987. Planned activities and areas of research are listed below:

Ozone Depletion

- Atmospheric data analysis
- Health effects
- Other effects
- Control evaluation and costs
- Benefits
- International Support
- Emissions
- Analysis/integration

Global Warming

- Sea level rise
- Ecological effects
- Water resources
- Regional studies
- Climate change data
- Health
- Policy studies
- Research on impacts of climate change

Question 6: (a) and (b)

(a) What products utilize CFCs -- including those that contain CFCs as well as those that use CFCs during the manufacturing of the product?

(b) What is the quantity and percentage of total volume of CFC-related products that are (1) manufactured in the U.S. for domestic use, (2) manufactured in the U.S. for export, (3) manufactured for import by U.S. companies abroad, (4) manufactured for import by non-U.S. companies, and (5) manufactured by foreign competitors for foreign consumption?

Response

(a) and (b) A wide variety of industrial and consumer products are manufactured with CFCs or contain CFCs. Exhibit 6 (shown above in response to question 3) lists the major products. Data are currently being collected by the Department of Commerce on domestic and foreign production and trade in these products. Exhibit 8 lists current estimates of domestic consumption of these products.

EXHIBIT 8

DOMESTIC PRODUCTION OF CFC-RELATED PRODUCTS

Product	Production	Comments
Aerosol Products	--	Banned in the U.S. for nonessential applications
Rigid Foam a/	336,000 metric tons in 1985	Urethane Foam
	257,300 metric tons in 1985	Polystyrene Foam b/
Flexible Foam a/	450,000 metric tons in 1984	Slabstock Foam b/
	175,000 metric tons in 1984	Molded Foam b/
Refrigeration and Air Conditioning c/	9.8 million air conditioners for cars and light trucks in 1985	Additional "mobile" air conditioners are imported and exported
	11,000 retail food refrigeration systems in 1985	There are over 165,000 retail food stores in the U.S.
	8 million home refrigerators and freezers in 1985	
Electronic Equipment and Capital Goods	--	CFCs are contained in solvents used for a wide variety of products. Over 40,000 metric tons of CFC-113 was used for solvent applications in 1985. Approximately half was used for electronics cleaning, and half for metal cleaning.

a/ Source: Evaluation of Potential Ozone Depleting Substances Emissions and Controls, Volume I, Draft Report, Radian Corporation, 1986.

b/ Not all of this type of foam is made with CFCs.

c/ Source: Preliminary estimates by Radian Corporation.

Question 7

During testimony at the hearing, Mr. Negroponte indicated that the State Department opposed unilateral domestic action to control CFCs. Does the Environmental Protection Agency oppose domestic action? If so, how will this decision affect EPA's decision in regard to the consent decree to take action by May 1987.

Response

EPA recognizes its responsibility under Section 151 of the Clean Air Act to determine whether additional regulation of CFCs is warranted to protect stratospheric ozone. We do not necessarily oppose unilateral domestic action in the absence of an international protocol, but we intend to take into consideration the need for global action and the effect of unilateral action on achieving that goal.

Because of the global nature of this problem, our top priority is to obtain an international agreement which would address the risks and, therefore, serve as the basis for our domestic action. It appears that unilateral action would at best only serve as a stopgap measure, and that global action is required to fully safeguard the ozone layer. Moreover, it appears that unilateral action could adversely affect U.S. industry, and that trade restrictions could only ameliorate this effect in part. Finally, the question arises as to whether unilateral action would facilitate an international agreement by demonstrating U.S. commitment and leadership or, alternatively, compromise our bargaining position, allowing other nations to benefit from our actions while delaying their own.

EPA/STATE DEPARTMENT INTERNATIONAL INITIATIVES ON STRATOSPHERIC OZONE NEGOTIATIONS

The following steps have been taken jointly by EPA and the State Department, following the December 1-5, 1986 negotiation session in Geneva, to build international support for early conclusion of an effective protocol to protect the ozone layer from potentially harmful chemicals.

1. Ozone layer issues raised by U.S. during U.S.-Soviet bilateral environmental meeting in Washington, Dec. 13-17, and agreement obtained to hold early consultations on science of ozone depletion in Moscow.

2. Engaged UNEP -- by cable, telecons with U.S. Permanent Representative to UNEP in Nairobi, and during Washington visit by senior UNEP official -- to urge adherence to original negotiating timetable, and that UNEP increase its staff suppport for the preparatory work to help ensure success.

3. EPA Administrator Thomas called U.K. Environment Minister Waldegrave to seek his help in keeping to the negotiating schedule, and to explore ways of elevating the importance of the issue in Europe. Agreement was reached that early visits by U.S. experts coul help expand awareness and understanding.

4. Cable sent to EC capitals asking U.S. Mission EC and embassies to approach EC leadership to urge that steps be taken to ensure that EC negotiators come to Vienna with flexibility to negotiate across range of issues. U.S. Ambassador to EC met with EC Commissioner.

5. Issue has been placed on agenda of U.S.-EC bilateral discussion scheduled for Washington in late March.

6. Assistant Secretary of State Negroponte and Deputy U.S. Trade Representative Smith discussed ozone protocol with senior Japanese officials during separate visits to Tokyo. This followed cables requesting such consultations.

7. Issue also raised in Washington with Japanese Embassy officials, leading to invitation for U.S. team to visit Tokyo in March.

8. USIA "Worldnet" capability used for January 27 interactive briefing by State Department negotiator and NASA scientist for European experts and reporters in six capitals, with second briefing scheduled for February 11.

9. Consultation held with Canadian delegation, Jan. 29 in Washington, to exchange information and views about second negotiating session.

10. Ambassadors Negroponte and Benedick discussed ozone layer issue with Brazilian Minister of Environment.

11. Scientific team, involving representatives from NASA, NOAA and EPA, and including a prominent Norwegian modeller, was sent to Moscow for Feb. 3-8 discussions.

12. Second team, with similar composition plus the principal U.S. negotiator, was sent to Brussels, Paris and London, Feb. 2-5, to meet with senior policy makers from those countries plus the European Community (in advance of Feb. 13 meeting of EC Council). Meetings arranged by U.S. Embassies based on joint EPA an State requests.

13. Nordic nations advised that Feb. 3-6 meeting of ECE Working Group on Nitrogen Oxide Protocol (Geneva) can serve as forms for discussing status of ozone negotiations, and that EPA member of U.S. delegation will be prepared to participate in separate ad hoc meetings of interested parties.

SENATOR STAFFORD QUESTIONS

Question

When the committee last seriously examined the CFC issue in the late 1970s, industry representatives pledged that if there was any concrete evidence of ozone depletion, they would promptly abandon the use of CFCs and move to substitutes.

There is little credible dispute that ozone depletion has now been measured, and confirmed.

I assume that some of you have met with industry representatives. If so, could you please tell us when and whether they are now honoring the pledge made several years ago? Specifically, are DuPont and Allied supporting a worldwide ban on CFC production and use? And finally, is the administration holding firm in its position to eliminate CFCs?

Response

Our knowledge of the factors affecting the creation and destruction of stratospheric ozone has increased substantially since the late 1970s. Research findings have generally supported the basic hypothesis that chlorine from CFCs could contribute to depletion of ozone. At the same time, research has shown that the problem is far more complicated. For example, atmospheric concentrations of other gases are increasing, which could in part offset depletion in total column ozone abundance. In addition, the recent discovery of the Antarctic ozone losses shows that the layer, at least at this location, is subject to substantial seasonal changes. However, we still do not know if these changes are the direct result of increased use of CFCs, whether they are unique to Antarctica, or whether they are totally unrelated to these chemicals.

In light of the scientific findings on ozone depletion, both DuPont and the Alliance for a Responsible CFC Policy (of which DuPont and Allied are members) issued statements last fall supporting an international agreement limiting future growth in CFC use. While these statements fall far short of a promise to abandon use of these chemicals altogether, they nonetheless represent substantial movement on their part in recognizing that action is necessary to reduce risks. Both statements are attached for your review.

Based on discussions with major CFC producers, we believe that research efforts have been restarted to develop safer chemical alternatives to CFCs. However, these substitutes are likely to be more expensive than the current CFCs and (according to DuPont's policy statement) would only justify the required capital expenditures if regulatory or price incentives existed. If such existed, we have been told that substitutes could be available within

5-10 years, assuming no unforeseen problems were encountered (e.g., problems with toxicity). EPA has set up a panel of independent experts to review the available information on chemical substitutes and is also working with user industries to better determine any possible obstacles, from their perspective, to expedited movement to these alternatives.

The Administration has not altered its position, stated at the December negotiations, which called for a near-term freeze on emissions of CFCs -11, -12, and -113 and on Halons 1211 and 1301 and a longer-term scheduled reduction in emissions of these chemicals, leading to their near elimination (i.e., reductions of up to 95%), to be subject to periodic reassessment based on a review of scientific, technical, and economic information. We intend to hold firm to this position as we enter the next round of negotiations in late February.

DU PONT POSITION STATEMENT ON THE
CHLOROFLUOROCARBON/OZONE/GREENHOUSE ISSUES

In 1974, two U.S. scientists advanced the hypothesis that chlorofluorocarbons (CFCs) emitted at the earth's surface would gradually migrate to the stratosphere where they would break down to release chlorine which, in turn, would catalytically reduce the concentration of ozone. A reduction in ozone would permit more ultraviolet light from the sun to reach the earth's surface with possible adverse consequences such as increased incidence of nonmelanoma skin cancer and damage to some crops and marine life.

Concern over this hypothesis led U.S. government regulatory agencies in the mid-1970's to begin to phase out the use of CFCs as aerosol propellants -- the then largest use. Some other, but not all, CFC producing countries also took action shortly thereafter, although generally less severe. As a result, total worldwide combined production of CFCs declined and stayed below the 1974 peak level through 1983.

Since the theory was announced, Du Pont has actively promoted, sponsored, and conducted research to develop sound scientific understanding of the potential effects of chlorofluorocarbons on stratospheric ozone. Because the theory hypothesizes that ozone depletion would occur only gradually over a long period, and it was thought that answers to the scientific questions could be obtained in a fairly short period, we have reasoned that there was time to develop the needed scientific understanding without harm to health or to the environment. This assessment, in combination with no growth in total worldwide CFC production, led us to take the position in the late 1970's and early 1980's that further regulatory decisions should await the findings of the scientific research. Our position has been supported by actual measurements which show no

As of now, we do not have a good knowledge of how much warming is likely, when it might occur, or the magnitude of any potential impact. As with the ozone issue, resolution of the uncertainties surrounding an increased greenhouse effect probably will take many more years.

Over the last few years, total worldwide CFC use has begun to grow again and total combined production has reached the pre-regulation levels of the mid-1970's. Although we continue to believe that no immediate hazard to health or the environment exists from current levels of CFC emissions, the wisdom of permitting continued growth must be weighed against the existing inability of the science to specify a safe long-term growth rate. Resolution of this and other key scientific uncertainties in the ozone issue and greenhouse effects could take decades; therefore, we conclude that it now would be prudent to limit worldwide emissions of CFCs while science continues to work to provide better guidance to policymakers.

Because these environmental issues are global in nature and because there are signficiant trade and economic equity questions associated with control measures, only cooperative action among countries will be effective. Therefore, Du Pont supports the development and adoption of a protocol under the United Nations Vienna Convention for the Protection of the Ozone Layer to limit worldwide CFC emissions.

We also call upon the United States EPA to employ the regulatory negotiation process for these issues and to appoint an advisory committee consisting of CFC users, producers, environmental groups, and the appropriate federal agencies. Consensus on the future of CFCs developed in this process could be used to guide the U.S. Department of State in international negotiations and to establish the basis for any further U.S. regulation consistent with international agreements.

DU PONT

E. I. DU PONT DE NEMOURS & COMPANY

WILMINGTON, DELAWARE 19898

CHEMICALS AND PIGMENTS DEPARTMENT

September 26, 1986

Dear Freon® Customer:

We are writing to further update you on the chlorofluorocarbon (CFC)/ozone issue and greenhouse effect and to alert you to a change in Du Pont's position. We now conclude that it would be prudent to take further precautionary measures to limit the growth of CFCs worldwide. This change has come about in the course of a careful review of the issue over the past few months -- one of a series of such assessments we have made since the 1974 inception of the ozone depletion hypothesis.

Although much progress has been made over the last twelve years in understanding the potential effects of CFCs and other gases on the atmosphere, many uncertainties remain. Unfortunately, resolution of the scientific questions and uncertainties surrounding the CFC/ozone issue has proved to be much more difficult and time-consuming than originally anticipated, and we now believe that many more years of research will be needed. In addition, recent developments in atmospheric science have raised a number of new questions: Do CFCs contribute to the seasonal "hole" in the Antarctic ozone? Are recent preliminary satellite measurements of depletion in total ozone valid? If so, are CFCs involved? And, in that neither of the above effects is predicted by the ozone depletion hypothesis, is the atmosphere much more fragile than had been thought?

Most of the computer models used to calculate potential future effects on the atmosphere continue to show no significant depletion of total overhead ozone for at least the next several decades <u>assuming</u> CFC emissions levels hold at current levels. However, CFC use worldwide is again growing, and the science is not yet sufficiently developed to define with certainty a safe CFC emissions growth rate. Further, all of the existing models now predict that high sustained CFC growth rates (i.e., leading to emissions levels three to five times current levels) would result in significant ozone depletion some 40 to 50 years in the future.

Recently, CFCs also have been linked to a new concern, the greenhouse effect. At current use levels, CFCs are calculated to contribute up to 15 - 20 percent of this potential future warming of the atmosphere, but could contribute up to 50 percent

of this effect if CFC emissions continue to grow unchecked. The timing, magnitude, and implications of both the ozone depletion and greenhouse effects remain highly uncertain, but the science community is concerned about the predicted effects of CFC growth scenarios.

Because of the new questions and concerns, the inability of science to define a safe, sustainable emissions growth rate for CFCs, and the fact that resolution of these and other uncertainties is not likely in the near term, we have concluded that it now would be prudent to take further precautionary measures to limit CFCs worldwide while the science works to provide policymakers with better guidance. We intend, therefore, to actively support the U.S. Department of State's effort to negotiate a worldwide CFC protocol to control emissions of fully halogenated CFCs under the United Nations Vienna Convention for the Protection of the Ozone Layer. Further, we will recommend that EPA enter into the "regulatory negotiation process" on CFCs and appoint an advisory committee of CFC users, producers, environmentalists, and appropriate government agencies to reach a consensus on the future of CFCs in the U.S. This consensus would be used to guide the State Department in its negotiations and serve as the basis for any needed further U.S. regulation.

In the mid-1970s, Du Pont began a research program to develop safe, environmentally acceptable, and commercially viable alternatives to the specific types of CFCs involved in the ozone issue (primarily CFC-11, 12, 113). Our findings, published in 1980, concluded that there were a number of alternative compounds which both met the environmental safety criteria and possessed the physical properties required for application in some (but not all) of the existing market uses of the CFCs of concern. One of these alternates, F-22, is already produced in large quantities and could be employed more broadly in refrigeration and air-conditioning in place of CFC-12 if appropriate use equipment were developed.

Neither the marketplace nor regulatory policy, however, has provided the needed incentives to make these equipment changes or to support commercialization of the other potential substitutes. If the necessary incentives were provided, we believe alternates could be introduced in volume in a time frame of roughly five years. This lead time would be needed to complete required toxicity testing, to design and build production facilities, and to make the necessary changes in applications equipment. We have recently reviewed and updated our earlier work and will share our assessment of the technically viable substitutes with you - our customers - and with EPA in the coming months.

In the meantime, we also will be reviewing processes and procedures to improve CFC conservation and recovery practices, and we will work with you to achieve this goal so that the potential for future harm to the environment can be reduced while essential uses of CFCs can be maintained.

Other developments in the CFC/ozone/greenhouse issues we believe you should know about follow:

- Science

  The measurement of seasonal ozone reductions over the South Pole (the "Antarctic Ozone Hole") has generated a major research effort by the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), and the Chemical Manufacturers Association (CMA). There are a number of speculative theories about the cause, including: chlorine from CFCs, solar-cycle effects, atmospheric dynamics, and others. The key concern is that this observation comes as a complete surprise to the atmospheric science community. A solid explanation for the "hole" is not likely for at least a couple of years.

  In an unrelated development, a new analysis of satellite measurements shows apparent decreases in total ozone over the past six to seven years. NASA scientists are hard at work checking the accuracy of correction factors used to account for the reduced sensitivity of the measuring instrument with time and assuring that stratospheric dust is not interfering with the measurements. However, even if the measurements are right, the cause is not explained by our current understanding of the science, just as with the Antarctic hole.

- United Nations

  The most recent activity in the United Nations Environment Programme's (UNEP) effort to reach agreement on a worldwide protocol (control measure) on CFCs was a September 8 - 12 workshop in Washington, D.C. to discuss the pluses and minuses of various control options. In December and February, negotiation sessions will be held between participating nations to attempt to reach agreement on what further should be done to control CFCs. A diplomatic conference is scheduled for April to reach final agreement. It is not yet clear what the outcome will be or even if the timetable can be met, but we expect that eventually some agreement will be reached. Many of us who have been following this process believe that some sort of cap on CFC production capacity will be the minimum step agreed to by the participants.

- EPA

  EPA states it is committed to work for a UNEP protocol, but it is under pressure to develop a unilateral program for the U.S. as well. This is because: 1) the complete UNEP process could take years, and many at the agency feel the time has arrived to take further steps now, and 2) EPA is working under a court-ordered settlement with the Natural Resources Defense Council (NRDC) to state its intent on CFC regulations by May and to propose its final plan by November, 1987. Although, in theory, EPA could find that no further steps are required, we expect that EPA will propose new regulations for CFCs.

- Congress

  Senator Chafee held hearings in June on the ozone and greenhouse issues, generating substantial and still increasing media interest. A second set of hearings may be scheduled to hear industry's views on what we are doing to resolve these issues, what currently could be used in place of CFCs, and what the prospects are for future CFC alternates. A bill to limit CFCs could result.

We have attached a more detailed statement of our new position and what led us to it. We welcome your questions and comments. In closing, let me assure you we are committed to work with you, our valued customers, through this coming period of regulatory uncertainty.

Very truly yours,

Joseph P. Glas

Joseph P. Glas
Director
Freon® Products Division

JGP/cna
Attachment

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PRESS ADVISORY

Embargoed For Release Until:
9:00 a.m., September 16, 1986

September 16, 1986

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Chairman
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ALLIANCE ISSUES NEW POLICY STATEMENT, SUPPORTS POSSIBLE GLOBAL CFC PRODUCTION CAPACITY CAP

Washington, D.C. -- The Board of Directors of the Alliance for Responsible CFC Policy approved a new seven point policy statement regarding U.S. policy on chlorofluorocarbons (CFCs), calling for the first time on the U.S. government to work "in cooperation with the world community under the auspices of the United Nations Environment Programme (UNEP) to consider establishing a reasonable global limit on the future rate of growth of fully halogenated CFC production capacity."

The Alliance plans to meet with appropriate U.S. government officials, including representatives at EPA and the State Department, Members of Congress, and environmental organizations representatives to discuss this new policy statement. The Alliance also plans to encourage its members to work with their industry associations to promote voluntary conservation programs consistent with this policy.

The policy statement was announced by Alliance Chairman Richard Barnett following the approval by the Board at its meeting on September 4th. Barnett said that the Board considered the statement to be an outline of responsible U.S policy with regard to CFCs that is "compatible with current scientific understanding and consistent with the original goals of the CFC Alliance."

The policy statement calls for the adoption, if necessary, of a reasonable global limit on future growth of fully halogenated CFC production capacity; the adoption of voluntary conservation programs by CFC end users where economically and technologically practical; the continuation of research into substitutes for fully halogenated CFCs; the continuation and coordination of international scientific research on the ozone depletion theory; and the avoidance of further unilateral regulation of CFCs by the United States and/or regulation of specific CFC uses.

* more *

ALLIANCE FOR RESPONSIBLE CFC POLICY
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Embargoed For Release Until:
9:00 a.m., September 16, 1986

POLICY STATEMENT

Chlorofluorocarbons (CFCs) are widely used by industry and the general public and contribute significantly to the quality of life in the United States and around the world because of their unique and beneficial combination of functional properties and excellent safety characteristics. The Alliance for Responsible CFC Policy was organized in 1980 to ensure that government policies regarding the further regulation of CFCs are responsible and that any such policies are based on sound scientific facts. It was a further objective of the Alliance to encourage that efforts be pursued on an international basis to resolve the scientific uncertainties pertaining to the ozone depletion theory, the role of CFCs, and the need, if any, for global action to protect the ozone layer. Since 1980, significant scientific research has been conducted concerning the ozone depletion theory, the greenhouse effect, and the role of CFCs. Significant scientific uncertainties remain, however, and the research needs have grown much more complex. Based on the theory, current scientific understanding, and reasonable assumptions about future emissions of substances that may modify the ozone layer, no significant modification of the ozone layer is expected during the next few decades, therefore, there is no imminent threat to human health and the environment from current CFC use or emission. On this basis, the Alliance believes that the following position statement provides an outline for responsible U.S. policy with regard to CFCs compatible with current scientific understanding and consistent with the original goals of the Alliance:

* Recognizing the global nature of the ozone depletion theory, the Alliance supports international resolution of the issue. Additional unilateral regulation of CFCs by the United States would provide little, if any, environmental protection, injure U.S. industry to the benefit of international competition, and may undermine efforts to obtain an international resolution.

* Additional scientific research is essential. The Alliance supports the atmospheric research recommendations contained in the January, 1986 NASA/World Meteorological Organization Science Assessment.

* Voluntary conservation in CFC end uses should be continued and expanded where economically and technologically practical.

* Regulation of specific uses of CFCs is ineffective and discriminatory.

* Responsible policy dictates, given the scientific uncertainties, that the U.S. government work in cooperation with the world community under the auspices of the United Nations Environment Programme to consider establishing a reasonable global limit on the future rate of growth of fully halogenated CFC production capacity.

* Development of alternative products and processes should be encouraged to utilize suitable alternatives to fully halogenated CFCs.

* Research should be continued and expanded to develop substitutes for fully halogenated CFCs.

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STATEMENT

OF

RICHARD BARNETT
CHAIRMAN
ALLIANCE FOR RESPONSIBLE CFC POLICY

SEPTEMBER 16, 1986
National Press Club
Washington, D.C.

Good Morning Ladies and Gentlemen:

I have a brief statement that I will read after which I will be happy to answer your questions.

The Alliance for Responsible CFC Policy was organized six years ago to represent the interests of users and producers of chlorofluorcarbons (CFCs). This was in response to what we considered to be an unwarranted proposal by the U.S. Environmental Protection Agency (EPA) to cap and eventually reduce production of this unique family of chemicals which have contributed so significantly to the quality of life of all Americans and to people around the world. The proposed EPA action was based on the theory that CFCs are emitted into the atmosphere and, because of their unique stability, eventually reach the earth's protective ozone layer, where they may deplete the ozone through a complex series of reactions.

In the belief that government ought not regulate based on an unproven or unverified theory, Alliance members established some basic goals with regard to the ozone depletion theory, CFC usage, and potential government policies.

First, it was our desire to encourage the pursuit of adequate credible scientific research on this important environmental issue, and then to ensure that any government policy be based on the best and most current scientific information;

Second, it was our goal to encourage efforts to resolve this issue in the international arena because of its global scope and to prevent any unproductive, harmful, unwarranted unilateral domestic regulatory program that would injure U.S. industry to the benefit of our international competition;

Third, it was our goal to amend the Clean Air Act to provide greater international emphasis on this issue and to give better guidance to the EPA Administrator regarding stratospheric ozone protection activities and the need for regulation.

In the six years that have gone by, we feel that much has been accomplished to obtain our goals, but we believe that much remains to be done.

We have seen wide swings of findings from conflicting scientific reports regarding CFCs and ozone depletion. With as much as we have learned from the intensive scientific scrutiny, we have also learned that there is a lot we still do not know. We believe the scientific research must continue.

In the intervening years, the Alliance has informed our political leaders, administrative officials, and the public-at-large, as to the many benefits that CFCs offer to our society, in comfort control, food preservation and preparation, energy

efficiency, cleaning and sterilization processes, and many other uses, as well as the tremendous contribution to worker and consumer health and safety.

Additionally, we have been an active participant in efforts to promote greater international cooperation, as exemplified by our support for the Vienna Convention for Protection of the Ozone Layer, and our participation in domestic and international efforts to address ozone protection issues such as the recently concluded series of workshops sponsored by EPA and the United Nations Environment Programme.

As you can imagine, the Alliance's activities as a coalition require the active physical as well as financial participation of our member companies. We have worked to live up to our name and be an Alliance for responsible CFC Policy. To do so requires a constant evaluation of the complex scientific, economic, and environmental policy issues confronting us and maintaining and, if necessary, adjusting our position in accordance with the most current information available to us.

In 1980, the Alliance urged that at least 3 to 5 years was necessary to allow the scientific research to continue and to gather critical monitoring information regarding the projections being made by computer models. Therefore, the 1986 release of the NASA/WMO science assessment on stratospheric ozone was an important event with regard to our own continuing evaluation process.

In general, I want to stress that the Alliance does not believe that the scientific information demonstrates any actual risk from current CFC use or emissions. We recognize, however, the growing concern for potential ozone depletion and climate change as

a result of large future growth of CFC emissions and the buildup of many other trace gases in the atmosphere, and the concern with the discovery of unexplained phenomena such as the large reductions in ozone levels during the Antarctic spring.

The science is not sufficiently developed to tell us that there is no risk in the future. In fact, all of the computer models calculate that large future growth in CFC emissions may contribute to significant ozone depletion in the latter half of the next century.

We support further scientific research and believe that regulatory policies should be periodically reexamined in the light of additional research findings.

On the basis of current information, we believe that large future increases in fully halogenated CFCs (the most durable ones, thought to contribute most to ozone depletion) would be unacceptable to future generations and, in our view, it would be inconsistent with the goals of this Alliance to ignore the potential for risk to those future generations.

The Alliance, therefore, believes that a responsible policy is necessary that meets four criteria. The policy must

-- provide some assurance that we never reach the "doomsday" scenarios that have been put forth;

-- foster the spirit of international cooperation needed to reach scientific consensus on this issue and the need for an appropriate global response;

-- fulfill our responsibilities as businessmen and women to our shareholders, employees, and customers; and

-- recognize the substantial contributions that CFCs make to the quality of our lives, and to the health, safety, and economic benefit of workers and consumers alike.

I am pleased to announce to you today, that the Alliance Board of Directors approved the following policy statement on September 4th. We believe this policy statement meets the criteria I have just stated. It reads: (READ POLICY STATEMENT)

I believe that this policy is a significant step in the direction of developing a positive approach to the issue of global ozone protection and the responsible use of CFCs. We recognize that the process of developing these prudent precautionary measures and establishing specifics will not be easy. As a coalition of many companies and industries, we may expect more specific policy suggestions from our members. We look forward to contributing to the development of the broader consensus on this issue, and hope that others will join us in a spirit of international cooperation as we pursue the difficult tasks necessary to achieve a global policy consensus in the months and years ahead.

Thank you.

CHLOROFLUOROCARBON/OZONE/GREENHOUSE ISSUES

In 1974, two U.S. scientists advanced the hypothesis that chlorofluorocarbons (CFCs) emitted at the earth's surface would gradually migrate to the stratosphere where they would break down to release chlorine which, in turn, would catalytically reduce the concentration of ozone. A reduction in ozone would permit more ultraviolet light from the sun to reach the earth's surface with possible adverse consequences such as increased incidence of nonmelanoma skin cancer and damage to some crops and marine life.

Concern over this hypothesis led U.S. government regulatory agencies in the mid-1970's to begin to phase out the use of CFCs as aerosol propellants -- the then largest use. Some other, but not all, CFC producing countries also took action shortly thereafter, although generally less severe. As a result, total worldwide combined production of CFCs declined and stayed below the 1974 peak level through 1983.

Since the theory was announced, Du Pont has actively promoted, sponsored, and conducted research to develop sound scientific understanding of the potential effects of chlorofluorocarbons on stratospheric ozone. Because the theory hypothesizes that ozone depletion would occur only gradually over a long period, and it was thought that answers to the scientific questions could be obtained in a fairly short period, we have reasoned that there was time to develop the needed scientific understanding without harm to health or to the environment. This assessment, in combination with no growth in total worldwide CFC production, led us to take the position in the late 1970's and early 1980's that further regulatory decisions should await the findings of the scientific research. Our position has been supported by actual measurements which show no

persistent change in total global atmospheric ozone over the last 20 years, and by computer model simulations of the atmosphere which predict no significant change in total ozone over at least the next several decades.

During the past twelve years, research by industry, government, and academia has made significant progress in broadening our understanding of the atmosphere, but also has made us much more aware of its enormous complexity. Several aspects of the theory have now become well defined, but the overall uncertainties regarding the potential long-term effects of CFCs on ozone remain large, and we now conclude that it will be many more years before an adequate scientific understanding can be achieved. Furthermore, although the science continues to indicate no immediate danger from CFCs at current emissions levels, the science is not yet sufficiently developed to define with certainty a safe CFC emissions growth rate, and all the models now predict that high sustained CFC growth rates (i.e., leading to emissions levels 3-5x current levels) would result in significant future ozone depletion.

It also has become apparent that the computer models will have to be upgraded, taking into account even more complex chemistry, physics, and meteorology. And the computer calculations must be tested against improved and more comprehensive physical measurements of chemical species in the atmosphere in order to increase our confidence in the predictive accuracy of the models.

Recently, the contribution of CFCs to the greenhouse effect also has been cited as a matter of concern. Although the greenhouse effect is essential in maintaining the earth at its current habitable temperatures, increases in atmospheric concentrations of carbon dioxide, nitrous oxide, methane, and CFCs might increase that effect beyond a societally acceptable level. Additional greenhouse warming could lead eventually to rising sea levels and altered rainfall patterns, with implications for coastal areas and agriculture.

As of now, we do not have a good knowledge of how much warming is likely, when it might occur, or the magnitude of any potential impact. As with the ozone issue, resolution of the uncertainties surrounding an increased greenhouse effect probably will take many more years.

Over the last few years, total worldwide CFC use has begun to grow again and total combined production has reached the pre-regulation levels of the mid-1970's. Although we continue to believe that no immediate hazard to health or the environment exists from current levels of CFC emissions, the wisdom of permitting continued growth must be weighed against the existing inability of the science to specify a safe long-term growth rate. Resolution of this and other key scientific uncertainties in the ozone issue and greenhouse effects could take decades; therefore, we conclude that it now would be prudent to limit worldwide emissions of CFCs while science continues to work to provide better guidance to policymakers.

Because these environmental issues are global in nature and because there are signficiant trade and economic equity questions associated with control measures, only cooperative action among countries will be effective. Therefore, Du Pont supports the development and adoption of a protocol under the United Nations Vienna Convention for the Protection of the Ozone Layer to limit worldwide CFC emissions.

We also call upon the United States EPA to employ the regulatory negotiation process for these issues and to appoint an advisory committee consisting of CFC users, producers, environmental groups, and the appropriate federal agencies. Consensus on the future of CFCs developed in this process could be used to guide the U.S. Department of State in international negotiations and to establish the basis for any further U.S. regulation consistent with international agreements.

Because CFCs have so many essential uses around the world, Du Pont began a research program in the mid-1970s to identify and develop safe, environmentally acceptable, and commercially viable alternatives. Our findings, published in 1980, concluded that there were a number of alternative compounds which both met the environmental safety criteria and possessed the physical properties required for application in some (but not all) of the existing market uses of the CFCs of concern. One of these alternates, F-22, is already produced in large quantities and could be employed more broadly in refrigeration and air-conditioning in place of CFC-12 if appropriate use equipment were developed.

Neither the marketplace nor regulatory policy, however, has provided the needed incentives to make those equipment changes or to support commercialization of the other potential substitutes. If the necessary incentives were provided, we believe alternates could be introduced in volume in a time frame of roughly five years. This lengthy lead time would be needed to complete required toxicity testing, to design and build production facilities, and to make the necessary changes in applications equipment. We have recently reviewed and updated our earlier work and will share our assessment of the technically viable substitutes with EPA and our customers in the coming months.

Finally, we believe it is important for the CFC producer and user industries to develop improved conservation and recovery practices to reduce atmospheric emissions of CFCs. Du Pont is studying a variety of technical and administrative approaches to reduce emissions and will share our views with the appropriate audiences in the coming months.

QUESTIONS FROM SENATOR CHAFEE

INTERNATIONAL PARTICIPATION

Question 1

How many countries have signed the Vienna Convention?

Response

As of February 1987, 28 countries had signed the Vienna Convention, including all of the major producing countries except Japan.

Question 2

How many have ratified or accepted it?

Response

As of February 1987, the following had ratified or accepted it: the U.S., Canada, Norway, Finland, Sweden, USSR, Byelorussian SSR, and Ukrainian SSR.

Question 3

Which major CFC-producing or -consuming nations have not signed, ratified, or accepted it?

Response

The members of the European Communities (EC) have not yet ratified the Convention. Japan has not yet signed the Convention.

Question 4

How many countries participated in the December meeting?

Response

Twenty-five countries participated in the December meeting.

Question 5

Which countries were conspicuous by their absence in December?

Response

Key absences from the December negotiations included China, India, Kenya, Nigeria, and EC members Ireland, Spain, and Greece. Belgium was represented on a limited basis by a Geneva mission officer.

Question 6

Were developing countries adequately represented?

Response

The developing countries were not adequately represented at the December negotiating session. Although the U.S. encouraged UNEP in advance to ensure strong LDC participation, and even contributed travel funds, only Brazil, Egypt, and Argentina sent representatives. (Mexico was represented by a Geneva mission officer.) Directly and through UNEP, we have urged expanded participation by Third World Countries in future sessions.

DECEMBER NEGOTIATIONS

Question 1: (a) and (b)

The State Department cable report on the December session says that the, "meeting was very useful in defining a common understanding of key concerns and options on which an effective second session depends."

(a) What are those "key concerns"?
(b) What are the "key options"?

Response

(a) "Key concerns" refers to the necessary components of an effective protocol, and include: the timing and stringency of the first steps to control chemical emissions; the structure and schedule of a strategy for reductions over the long term; how to establish an adequate scientific review mechanism; how to treat developing countries that may wish to use these chemicals in the future; how to create incentives/disincentives for non-parties, including trade restrictions; and the scope of chemicals to be covered in the protocol.

(b) "Key options" refers to the various proposals by participating countries (e.g., U.S. position; Canadian and Soviet production allocation formulas; EC production freeze; Canadian/Nordic adjusted production formula). With this information we are better able to prepare for and influence the second round of negotiations.

Question 2: (a), (b), and (c)

Again according to the cable report, the meeting was notable for the "absence of debate specifics."

(a) How do you see the debate on specifics proceeding?

(b) When?

(c) What is the time frame for future negotiations and a wrap-up diplomatic conference?

Response

(a) and (b) We anticipate more debate on specifics at the Vienna session in late February. We have consulted and sent to UNEP a listing (reinforced by Canada) of specific protocol elements and issues we believe important (see attached letter). The session should better focus discussion on both short- and longer-term strategies for limiting emissions of ozone-depleting chemicals.

(c) We have succeeded in maintaining the original schedule, which calls for a second session in February (23-27) followed by a diplomatic conference in April if sufficient progress is realized. While additional sessions may be required, we are approaching the Vienna meeting with a view to completing work on as many specific issues as is possible. An additional session might be held in April/May and a Diplomatic Conference in early July, or, if necessary, a Diplomatic Conference could be held in September.

Question 3: (a), (b), and (c)

At the December meeting, the U.S. "focused its efforts on ensuring broad support for basic elements of a protocol which would have both meaningful near and long-term control measures".

(a) Were you successful?

(b) Which countries are resisting long-term controls?

(c) Was there any discussion of short-term reductions on the order of 25% or 30%?

Response

(a) We were not successful in getting agreement on a long term control component. However, the scope of the desired protocol and specific components were not adequately debated, so it was not possible to be "successful" at that time.

(b) From the general discussion in Geneva, and from subsequent exchanges, it appears that the EC, Japan, and the USSR may be resistant to a scheduled reduction of emissions.

(c) There was no discussion in December of short-term reductions of 25-30%, other than a Nordic amendment to the U.S. text. The Nordic proposal, which calls for a 25% reduction by 1991, did not engender any specific responses in highly generalized, wide-ranging discussions.

Question 4

The U.S. also focused on covering "the broadest spectrum of ozone-depleting chemicals." Where do the various countries stand on that issue?

Response

Canada and the Nordic nations agree with the U.S. on a broad spectrum approach. The other nations that have spoken out on this -- the EC, Japan, and the Soviet Union -- favor much more restrictive coverage. The EEC is considering inclusion of CFC-113 and -114; Japan and the USSR favor including only CFC-11 and -12.

TRADE ISSUES

Question 1: (a), (b), and (c)

I understand you have a U.S. working group on trade issues.

(a) Who are the members of this group?

(b) What is the status of the group?

(c) What specific issues are they looking at?

Response

(a) The group working on trade issues includes representatives of the Departments of State and Commerce, the Environmental Protection Agency, and the Office of U.S. Trade Representative.

(b) and (c) The group has considered the following issues:

1. Are options under consideration consistent with GATT and other international legal obligations?

2. What method should be used for calculating national limits (production vs. adjusted production)?

3. Are restrictions on exports of technology and/or investments necessary? advisable? enforceable?

4. Should the protocol restrict trade in bulk CFCs, products containing CFCs, and/or products made with CFCs? Can such restrictions be used to:

   (a) Make the agreement more effective by providing incentives to join?

   (b) Make the agreement as fair as possible to U.S. manufacturers competing in the U.S. and Third World markets?

   (c) Discourage movement of capital offshore by restricting markets for the products of non-party production?

   Would the benefits of trade restrictions outweigh the administrative costs to government and industry?

Question 2: (a), (b), and (c)

Since there is relatively little international trade in bulk CFCs, we must restrict trade in products if a protocol or domestic actions are to be effective.

(a) Has the U.S. Trade Representative examined the GATT implications of this?

(b) Are they preparing a report? If so, when will it be ready?

(c) We need this information with respect to products containing the controlled chemicals as well as products made with, but no longer containing, the controlled chemicals. Could you supply such an analysis for the record?

Response

The U.S. Trade Representative has examined the GATT implications of possible trade restrictions to protect the environment. The memorandum on trade law issues and ozone layer negotiations, authored by Associate General Council Amelia Porges, is attached.

OFFICE OF THE UNITED STATES
TRADE REPRESENTATIVE
EXECUTIVE OFFICE OF THE PRESIDENT
WASHINGTON
20506

January 14, 1986

MEMORANDUM

TO: CFC Trade Work Group

FROM: Amelia Porges AP
Associate General Counsel

SUBJECT: Trade Law Issues and Ozone Layer Negotiations

Negotiations have now begun on a Protocol to the Vienna Convention for the Protection of the Ozone Layer. This protocol would be the basis for an international regime for the regulation of production and trade in chlorofluorocarbons (CFCs). You have asked about trade law considerations relevant to the design of this regulatory regime. The following discussion is necessarily abstract at this point, and can only flag possible problems. Pep Fuller, Bob Reinstein and I will be glad to answer more concrete questions on trade policy and trade law as the negotiations develop.

As long as the trade restrictions imposed are related to the conservation of natural resources, or necessary to the protection of human, animal or plant health, nothing in the GATT will prevent their adoption as long as they are not a disguised restriction on international trade. Similarly, all that is required to satisfy the GATT Standards Code is that the standards set be scientifically valid. Thus, any rule that satisfies the requirements of U.S. law (the Clean Air Act) will probably satisfy the GATT and the Code (and bilateral FCN treaties).

A trade regime for CFCs may require that the parties discriminate against CFC trade from non-parties. This raises two technical issues worth thinking about: dealing with transshipment of goods from non-parties to parties, and designing a rule of origin for the products subject to the protocol. Both can be dealt with, in the protocol itself and/or in national implementation of the protocol.

GATT and the Standards Code

GATT (the General Agreement on Tariffs and Trade) regulates our trade relations with its ninety members. All of the current signatories of the Vienna Convention on the Protection of the Ozone Layer are also GATT contracting parties, with the exception of Morocco, which is in the final stages of GATT accession, and

the USSR and Byelorussian and Ukrainian SSRs. GATT confers rights and obligations on its members with respect to imports and exports of products from its member countries. It does not regulate government treatment of foreign firms, nor does it regulate services, investment or technology transfer.

The GATT generally bans quantitative restrictions on imports or exports, and prohibits import charges in excess of tariff concessions; these strictures would apply to any restriction on trade except if imposed under one of the exceptions provided in the GATT. However, GATT Article XX provides:

> Subject to the requirement that such measures are not applied in a manner which would constitute a means of arbitrary or unjustifiable discrimination between countries where the same conditions prevail, or a disguised restriction on international trade, nothing in this Agreement shall be construed to prevent the adoption or enforcement by any contracting party of measures: ...
>
> (b) necessary to protect human, animal or plant life or health;
>
> (g) relating to the conservation of exhaustible natural resources if such ~~measures~~ restrictions are made effective in conjunction with restrictions on domestic production or consumption;...

Under Article XX, the members of the agreement could impose a ban or restriction or import fee on imports of CFCs (or products made with or containing CFCs) to the extent that such action is <u>necessary</u> to protect human, animal or plant life or health, <u>and</u> if the measure does not treat like cases differently. Similarly, we could certainly justify ozone-related trade measures as relating to the conservation of the ozone layer, an exhaustible natural resource, since the parties to the agreement would presumably be applying restrictions on domestic production or consumption.

Nothing in the GATT would prohibit a party from applying trade restrictions against all non-signers (regardless of whether they actually conform to agreement standards) on the basis that they have not formally acceded to the agreement. For instance, Japan and Norway have notified the GATT that they prohibit all imports of whalemeat from countries not signatories to the International Whaling Convention.[1]

The standard in Article XX(~~f~~ g) is a very broad one. It could

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[1]GATT/L/4814, L/5165.

Bilateral Treaties

The U.S. has entered into many bilateral friendship, commerce and navigation (FCN) treaties over the years. Most FCN treaties were negotiated by the U.S. from 1945-62, based on a standard draft text. There are two treaty provisions of concern in the context of a CFC regime: most-favored-nation treatment (which requires that we give products of the treaty partner treatment no less favorable than treatment given to products of any other party), and national treatment (which requires treatment no less favorable than treatment given our own products). These provisions are contained in almost all of the 1945-62 FCNs, and (in some form) in many other of our bilateral trade treaties.

However, Article XXI, paragraph 3 of the standard FCN draft permits any action that is specifically permitted by the GATT. Thus, any action permitted by GATT Article XX is permitted under the standard FCN text.

The treaty question should be re-examined when it is clearer what the obligations of the protocol are likely to be, and who the participants and non-participants are likely to be.

Transshipment and Rules of Origin

A trade regime for CFCs could require agreement members to discriminate in their trade between the products of members and non-members. This raises two questions: first, how to deal with transshipment or diversion, and second, how to determine the origin of imports. These are both essentially technical issues that you may wish to raise in a later stage, when the trade aspects of the protocol have taken shape.

Transshipment is an issue whenever there is a trade regime that discriminates by origin. For instance, the International Coffee Agreement[4] provides that in times of oversupply and low coffee prices, exporting members are to be subject to export quotas, and importing members are to enforce these quotas through limiting their imports from ICA members to coffee that has a an export license issued by an exporting member.[5] Where a country has filled its export quota (and, under the ICA, therefore ceases issuing export licenses) its exporters may be tempted to transship

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[4]International Coffee Agreement, 1983, TIAS ___-, done at London Set. 16, 1982, entered into force definitively Sept. 11, 1985.

[5]A limited amount of imports from non-members is permitted, but the level of imports is set low enough to provide a strong incentive for coffee exporting countries to join.

conceivably permit sanctions against non-CFC trade of all non-signers, if such sanctions could be defended as environmentally motivated and as a functioning part of the agreement.. Note that measures under XX(g) need not be necessary to the conservation of exhaustible natural resources-- just related to such conservation. For GATT purposes, the closer the relation, the better.

In order to introduce greater discipline and transparency in national regulatory systems affecting trade, the Agreement on Technical Barriers to Trade[2] (commonly known as the Standards Code) was negotiated under GATT auspices in the Tokyo Round, and entered into force in 1980. All but a few developed countries are members of the Code, and many developing countries (although there are no members that are not GATT members).

The Code does not interfere with the adoption per se of regulations that meet real health and safety needs. Rather, it sets rules for setting standards and maintaining certification systems. One of these rules is that standards-setting and certification systems should not create unnecessary obstacles to international trade (this obligation is implemented with respect to USG regulatory activities in section 402 of the Trade Agreements Act of 1979 (19 U.S.C. 2532). The term "unnecessary obstacle" is not defined in the Code and has not been interpreted by the Standards Code Committee nor through disputes brought under the Code.

The Code covers the preparation, adoption and application of standards; determination of conformity with standards; and operation of certification systems. With regard to these activities, the Code generally requires that national and most favored nation treatment be accorded to products of other parties to the Code.[3] If a standard is scientifically justified (as U.S. law requires our standards to be), the Code will not stand in the way of its adoption as long as it imposes no unnecessary obstacles to trade.

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[2]Agreement on Technical Barriers to Trade (Standards Code), 31 UST 405, TIAS 9616, done at Geneva April 12, 1979, entered into force January 1, 1980.

[3]The Code does not cover regulation of processes and production methods, except where a party to the Code considers that Code obligations are being circumvented by the drafting of requirements in terms of processes and production methods rather than in terms of characteristics of products. See Standards Code Art. 14.25. A standard that prohibited the use of CFCs to clean electronics, and prohibited as well the importation of electronics that had been cleaned with CFCs, would be one example of regulation of processes or production methods.

coffee through a country that has not filled its quota and mislabel the coffee as being from the country of transshipment.[6] However, the customs laws of the United States and most countries provide substantial penalties for acts of this sort, which constitute customs fraud[7] through false labeling of origin. If exporters or importers of CFCs were to transship CFCs or CFC products in order to evade restrictions on imports from non-agreement countries, this would almost certainly constitute customs fraud.

The other issue is determining where goods are from, for the purposes of the regime that would govern trade in CFCs and/or products. If this regime does significantly restrict trade, the rule of origin may be an important issue.

If the products to be regulated here are produced in such a manner that the entire chain of production takes place in one country, determination of origin may be relatively straightforward. However, origin may not be so simple to decide for products of a multi-stage manufacturing process. Also, trade restrictions may lead producers to change the "origin" of products: after a U.S. antidumping order on televisions from Japan, for instance, the TV exporters shipped TV kits to Taiwan for assembly and export to the U.S. If CFC technology lends itself to this kind of evasion, and if such evasion would undermine the effectiveness of the agreement in practice, you may want to consider origin questions carefully in the protocol negotiations, and perhaps provide a uniform origin rule.

Cleared: Pep Fuller

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[6]Preferably, unused export quotas are redistributed to other member coffee exporting countries that are a position to use them.

[7]Entry of goods into the U.S. by means of false statements, regardless of whether the U.S. government is defrauded of duties, is punishable under 19 USC 1592 (civil customs fraud--subject to forfeiture of merchandise); 18 USC 542 (criminal customs fraud--$500 fine/2 years prison); and 18 USC 1001 (false statements to the Federal government).

Question 3

Since the EC countries and Japan seem to be the most reluctant participants, have you done a trade analysis focusing on them? Specifically, for each country, what products containing CFCs are exported to the U.S.? Similarly, what products made with, but no longer containing, CFCs are exported to the U.S.?

Response

No comprehensive list of all products containing CFCs or manufactured with CFCs has been prepared. Some products are relatively easy to identify, such as refrigerators, air conditioners, dehumidifers and other refrigerant equipment. For numerous other products CFCs might have been used to manufacture one or more of the product materials. CFCs are used as solvents in the manufacture of metal and electronics products, as foam-blowing agents for flexible foam and rigid foam (including packaging) and as dry-cleaning agents. Such a list would contain thousands of product categories and tens of thousands of particular products.

EPA is currently attempting to analyze trade of products containing CFCs and products made with, but no longer containing, CFCs. If possible, this analysis will be conducted on a region- or country-wide basis. There are significant difficulties in this analysis because trade data groups CFC products in broad categories and because the average quantity of CFCs in products that contain materials made with CFCs has not been estimated. The available information is summarized below in the response to Question 3 from Senators Mitchell and Baucus.

TESTIMONY OF
J. CRAIG POTTER
ASSISTANT ADMINISTRATOR FOR AIR AND RADIATION
U.S. ENVIRONMENTAL PROTECTION AGENCY
BEFORE THE
SUBCOMMITTEE ON HAZARDOUS WASTE AND TOXIC SUBSTANCES
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
U.S. SENATE

January 28, 1987

Good morning, Mr. Chairman and members of the Subcommittee. I am pleased to have the opportunity to discuss the current state of our knowledge of the changes in earth's atmosphere, the possible public health and environmental implications of these changes and what we at EPA are doing to address these issues both within the United States and in our international negotiations. With me today are Fitzhugh Green, Associate Administrator for International Activities, and Dr. Vaun Newill, Assistant Administrator for Research and Development. Our direction from the Administrator has been to place these issues among the Agency's highest priorities, and together, our offices spearhead EPA's efforts to understand and respond to these concerns.

Pollution that directly affects land, water, and the air we breathe has been the Environmental Protection Agency's traditional focus. However, the environmental significance of changes now occurring in the composition of the earth's atmosphere as a result of human activities presents a new and demanding challenge, and requires that all nations consider the effect of their actions on the atmosphere.

Obviously, our atmosphere plays a fundamental role in shaping and protecting our planet's environment. Sustaining its viability is of paramount importance to all nations, and true global cooperation is necessary if we are to ensure its protection. For it is possible that a shift in the atmosphere's chemical and physical balance could lead to two separate but related environmental and health concerns.

The first concern involves possible future depletion of the stratospheric ozone layer. Here our concern rests upon a growing body of scientific evidence which indicates that continued use of chlorofluorocarbons (CFCs) and other ozone-reactive substances could result in reducing the effectiveness of the atmosphere's outer protective ozone shield. We are certain that if enough chlorine and other halogens are put in the atmosphere, the ozone layer will begin to be depleted. The current state of science also tells us that the effect of a diminution in the stratospheric ozone layer would be to allow more damaging ultraviolet-B (UV-B) radiation to penetrate to the earth's surface causing increases in the number of skin cancers, suppressing the immune system, and possibly damaging crops and aquatic organisms.

The second related concern which I will just briefly describe relates to the greenhouse effect or global warming. We know that the concentrations of several gases including CFCs are increasing in the atmosphere. Some, like chlorofluorocarbons and sometimes nitrous oxide, contribute to stratospheric ozone depletion; while others, such as methane and carbon dioxide, can actually add to the ozone column or reduce losses. Yet all are greenhouse gases.

As such they block the escape of heat energy from the earth's surface, thus forming a thermal blanket and contributing to warmer temperatures.

In assessing the problems of stratospheric ozone depletion and the greenhouse effect, we must keep several things in mind. First, as mentioned earlier, both of these issues are examples of environmental problems which demonstrate how clearly we are part of a "global commons." Because CFCs and related ozone-reactors quickly disperse throughout the atmosphere, all nations should be concerned about recent changes in the atmosphere. Although the producing nations must shoulder primary responsibility, all nations will need to cooperate in any effective solution to these problems. The U.S. has already begun to meet its responsibility by taking a leadership role through the banning of non-essential aerosol uses. Seven other nations, including Canada and the Scandinavian nations, have also taken this important first step. However, we can and must do more. CFC use has returned to levels approximating those reached in 1974 before concern first surfaced about ozone depletion. Our studies have shown that if anticipated CFC production and use continue as projected, global use of CFCs can be expected to increase, with potentially significant effects on the ozone column.

A second thing to keep in mind in assessing these problems is the need to distinguish between the scientific process of risk assessment and the public policy process of risk management. Risk assessment looks specifically and exclusively at the scientific and technical evidence in order to determine the health and environ-

mental risks associated with depletion of the ozone layer. Risk assessment will have a particularly important role in evaluating the uncertainties associated with this issue.

Risk management, on the other hand, takes this risk assessment information as its starting point and determines which options are available to address the problem. Any course of action which the United States ultimately chooses must take into consideration the full spectrum of associated economic and social impacts, and must also recognize both the national and international aspects of the issue. Through the risk management process, and pursuant to our mandate under the Clean Air Act, we will make a determination of whether our nation will need to take additional specific actions to control risks related to stratospheric ozone depletion. EPA will make this decision publicly, with ample opportunity for comment by all interested parties.

We feel our risk assessment efforts in this area have led to a greater understanding of the problem of stratospheric ozone depletion and its implications. Decreases in total column ozone would increase the penetration of biologically damaging ultraviolet-B radiation reaching the earth's surface. Exposure to UV-B radiation has been linked by laboratory studies and epidemiology to squamous and basal skin cancers. While uncertainty exists concerning the appropriate action spectrum and measure of exposure, a range of estimates was developed linking possible future ozone depletion with increased incidence of nonmelanoma skin cancers.

The relationship between cutaneous malignant melanoma and UV-B radiation is a complex one. However, recent studies, some of which are financially supported by the Agency, suggest that UV-B radiation plays an important role in causing melanoma. Studies have also demonstrated that UV-B radiation can suppress the immune response system in animals and possibly humans. While UV-B induced immune suppression has been linked to herpes virus infections and leishmaniasis, its possible impact on other diseases has not been studied.

To support our risk assessment efforts, we have a continuing research program to assess the environmental effects of UV-B. Several hundred varieties of crop plants have been examined and some 140, about two-thirds, exhibit some level of sensitivity to increased UV-B radiation. Some of the crops are important human food sources and our work is not completed in this area.

Our aquatic research, mainly with marine environments, has shown marine organisms, especially plankton and larval forms, to be sensitive to increased UV-B; so sensitive that the species composition may be altered by this radiation. The ramifications of these responses on larger fish which are at the top of the food web are still being examined.

Modest research and modeling efforts are examining the role of increased UV-B radiation on other air pollutants in the troposphere to determine if they may enhance pollutant formation.

While work still needs to be done to quantify some of our research results, the research evidence clearly shows that increasing levels of UV-B are damaging to humans and many important plant and animal life forms both on land and in the sea.

Given these concerns, we have greatly expanded our efforts to better understand the risks and uncertainties associated with ozone depletion, and have factored our current understanding into our risk management activities.

In January of 1986, we announced our stratospheric ozone protection plan which sets forth a comprehensive agenda for dealing with both domestic and international aspects of this issue. This plan also formed the basis for settlement of a lawsuit filed by the Natural Resources Defense Council (NRDC) seeking to compel us to make a decision on the need for further domestic regulation.

I would first like to briefly describe what we have been doing recently in the international arena. As I mentioned earlier, the global aspects of this problem make it paramount that any true solution involve the other CFC producing and consuming nations. As a result, we have initiated a series of activities aimed at educating and encouraging other governments to support measures to reduce CFC use. Key activities include:

-- U.S. leadership in negotiating and ratifying the Vienna Convention for the Protection of the Ozone Layer, which provides a framework for international cooperation on research, monitoring, and information exchange, and procedures for developing control protocols as needed;

-- U.S. leadership in a two-part workshop organized by the United Nations Environment Programme (UNEP) which focused on key economic issues related to control of CFCs;

-- U.S. co-sponsorship with UNEP of an international conference on the effects of both ozone depletion and climate change.

This series of meetings--all during the past 12 months--provided the analytical basis for assessing the nature of the problem and the options for reducing global risks. But our efforts have gone well beyond sponsorship of these meetings. For example--

-- Lee Thomas sent letters to his counterparts in over 100 nations advising them that this issue was a very high priority and requesting their active participation in the UNEP negotiations.

-- We have also sent teams of scientists to other key nations as part of our effort to increase understanding of other risks if depletion should occur. Over the next two weeks, a team from NASA, NOAA, EPA, and State will be in Europe, and next week a scientific team will be in Moscow expressly to continue this dialogue.

-- We have participated actively in UNEP negotiations on a protocol to the Ozone Layer Convention.

Ambassador Negroponte will discuss the status of the international negotiations in greater detail in a few minutes. Let me just say here that the U.S. position -- a near-term freeze followed by a scheduled longer-term reduction of CFC emissions and use, subject to a periodic reassessment of the science -- has had the effect of altering the tone and content of the negotiations. We are now working hard to maintain the momentum and to broaden the level of international awareness and cooperation -- and looking to create and seize new opportunities to engage other nations in discussions of the science of ozone depletion as well as of measures needed to deal effectively with the problem.

On the domestic side of this issue, we are also moving forward rapidly. While we hope that we are able to reach a satisfactory international resolution of this issue in the near-term, we recognize that we face an obligation under the Clean Air Act to assess the need for further domestic regulation. The deadlines set forth in our plan, as mentioned earlier, are consistent with the court order negotiated with NRDC and others, calling for EPA to propose a decision on the need for further domestic regulation and, if warranted, specific regulations, by May 1, and to make a final decision by November 1 of this year.

To meet this deadline we have completed several steps:

-- In March and July of last year we held workshops in Washington attended by a wide range of interest groups. These workshops discussed alternative regulatory options and their economic impact;

-- In late November we submitted to a subcommittee of the Agency's Science Advisory Board -- convened specifically for the purpose of reviewing this issue -- our draft risk assessment document;

-- within the Agency we are now in the process of preparing a regulatory impact analysis and evaluating options for action, all key steps in our regulatory process.

While I cannot yet say what will be the outcome of this process, I can state that we are committed to making a decision and to meeting the timeframes that be have laid out in our January 1986 plan.

I would also like to note the significant contributions made by industry. Their attempts to find mutual areas of agreement and their general support for some form of international protocol are certainly encouraging developments and are illustrative of the growing consensus on the science and the need for action. I should also add that the interest and involvement of the environmental community and staff from both the Senate and House have substantially aided our efforts. The presence of these groups at this hearing and the fact that representatives of three EPA offices are here today should underscore the growing importance of this issue. Given the complex nature of this issue, widespread cooperation in both the national and international scene is essential to the future progress we all desire.

In summary, I believe that the activities I've just described are important first steps toward expeditiously and aggressively moving forward in our efforts to obtain an international agreement and to assess our domestic regulatory options.

I, Mr. Green and Dr. Newill would be pleased to attempt to answer any questions you may have.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

MAR 5 1987

OFFICE OF
AIR AND RADIATION

Honorable George J. Mitchell
Chairman, Subcommittee on
Environmental Protection
Committee on Environment and Public Works
U.S. Senate
Washington, D.C. 20510

Dear Mr. Chairman:

I am writing in response to your letter of January 30, 1987 in which you forwarded several follow-up questions from the January 28 hearing before the Subcommittees on Environmental Protection and Hazardous Wastes and Toxic Substances. A response to those questions is enclosed.*

I believe we have made considerable progress in dealing with this complex issue. I appreciated the opportunity to speak before your Subcommittee on this subject and I hope that the response to your questions will be useful.

Sincerely,

J. Craig Potter
Assistant Administrator
for Air and Radiation

Enclosure

*See response from the Department of State.

THE GREENHOUSE EFFECT AND CLIMATE CHANGE

By

Gordon J. MacDonald

Presented Before the
Subcommittee on Environmental Protection, Environment
and Public Works Committee
United States Senate
Washington, D. C.

January 28, 1987

THE GREENHOUSE EFFECT AND CLIMATE CHANGE

Presentation by Gordon J. MacDonald*
Before the Subcommittee on Environmental Protection, Environment and Public Works Committee
January 28, 1987

Thank you Mr. Chairman and members of the Committee. I very much appreciate the opportunity to discuss with you a major problem of our times, perhaps exceeded in global importance only by the possibility of nuclear war. The recognition of the significance of climate change by this Committee sets an admirable example of wise anticipation of future deleterious conditions prior to the time when these conditions overwhelm society with unexpectedly rapid changes.

The scientific basis for the greenhouse effect has been most ably dealt with by your panel of experts. Since this is a subject on which I have worked for more than 25 years, I have prepared a summary of my understanding of the science and have appended this summary to my formal testimony to be included, with your permission, in the record. The summary reflects in detail the material presented by your panel of experts. There is one point that I feel requires further emphasis. The primary impact of our artificial greenhouse is the gradual increase of the average temperature the world over. However, accompanying this slow shift will be a much enhanced variability in weather. The atmosphere-ocean system is a coupled dynamical system. A shift in the conditions within the system can bring about wild swings in local weather conditions as the system searches for its ever changing equilibrium state. An inadequate but relevant dynamical

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example is a wash basin and a faucet. When both faucet and plug are leaky, the basin's water level remains about the same and the only disturbances are the ripples sent out by the falling drops impacting the water. Pull the plug and open the faucet and conditions shift dramatically as the system attempts to achieve equilibrium. The turbulent slosh is far different than the relatively peaceful drip and leak. So it may be with the atmosphere and oceans. The historic drought in the southeast this past summer, the unprecedented European winter of this year, and the Sahel drought of the past decade may only be exceptional ripples in our leaky sink. Alternatively, they could be the beginning of the turbulent slosh as the plug is pulled and the faucet opened by man-made changes to the atmosphere.

You have asked me to comment on three questions.

(1) **Which energy uses contribute to the greenhouse effect?**

All burning of carbon-based fuels adds to the carbon dioxide burden of the atmosphere, the principal greenhouse gas. Since energy is derived from the chemical combination of carbon with oxygen, coal, oil, natural gas, and wood all contribute to the warming of the atmosphere, regardless of how the energy they generate is used.

Inefficient energy uses lead us to consume more carbon-based fuels. The more efficient the energy use, the less carbon dioxide is released per unit of useful work done.

The use of solar, hydroelectric, and nuclear energy does not directly affect the composition of the atmosphere. However, carbon-based fuels may be used in the construction of solar and nuclear generating and transmission facilities, so in net even these uses of energy can bring about small changes in atmospheric composition.

The greenhouse effect is created not only by carbon dioxide but by ozone, methane, and nitrous oxides, and it is indirectly affected by sulfur dioxide and carbon monoxide. All of these compounds form from the emissions of burned coal, petroleum, and natural gas. Solar and nuclear energy, except as noted earlier, do not raise the concentration of the trace greenhouse gases.

Your second question is:

(2) **Are there differences in greenhouse gas emissions among fuels?**

The simple answer is emphatically yes, as shown in Table 1.

TABLE 1

Carbon Dioxide Produced from Direct Combustion of Various Fuels

Fuel	Carbon Dioxide Generated (in pounds per million Btu of thermal energy)
Natural Gas	115
Propane	139
Gasoline	160
Diesel Oil	167
Bituminous Coal	200
Subbituminous Coal	215

Burning enough gasoline to produce a million Btus generates 30% more carbon dioxide than does burning natural gas to produce the same amount of heat. Bituminous coal produces almost 75% more carbon dioxide than does natural gas in delivering the same amount of energy. The chemical reason for these great differences is simple. The amount of chemical energy contained within a fuel is basically determined by the ratio of hydrogen to carbon. In natural gas, the ratio of hydrogen to carbon is 4; in gasoline, it is 2; and in coal it varies, but is about 0.8.

Of concern is the fact that over the past several years we have shifted the fuel mix in the direction of increasing those fuels whose contribution to the greenhouse effect is greatest. The total amount of carbon dioxide released into the atmosphere in the United States between

1975 and 1980 grew by 750 million metric tons as energy consumption increased. (See Table 2.)

TABLE 2

Carbon Dioxide Produced by Consumption of Energy
in the United States
(in billions of metric tons)

	Coal	Natural Gas	Petroleum	Total
1975	1.18	1.04	2.46	4.68
1980	1.44	1.06	2.57	5.07
1985	1.63	0.93	2.34	4.90

(Source: Energy Information Administration)

The increase of energy prices drove down energy consumption during the early 1980s, but energy consumption and greenhouse gas releases are once again increasing. With these gross changes have come differing contributions from the major fuels. (See Table 3.) For example, in 1975,

TABLE 3

Relative Contributions of Major Fuels to Energy Consumption and to Carbon Dioxide Production in the United States

	Coal		Natural Gas		Petroleum	
	% Energy;	% CO_2	% Energy;	% CO_2	% Energy;	% CO_2
1975	18	25	28	22	46	53
1980	20	28	27	21	45	51
1985	24	33	24	19	42	48

coal provided 18% of the energy consumed but produced 25% of the carbon dioxide. By 1985, coal was providing 24% of the energy while emitting 33% of the carbon dioxide. During this ten-year period, the consumption of the carbon-based fuel least damaging in the greenhouse context, natural gas, went down. The use of the most damaging fuel, coal, increased both relatively and in absolute terms.

The biggest increase of coal use has come in the electrical utility sector of the economy. (See Table 4.) While nuclear power has become an

TABLE 4

Relative Contribution of Major Fuels to Energy Consumed in Electrical Utilities and to Carbon Dioxide Produced in the United States

	Coal		Natural Gas		Petroleum		Nuclear, Hydropower, and Other	
	% Energy;	% CO_2	% Energy;	% CO_2	% Energy;	% CO_2	% Energy;	% CO_2
1975	43	67	16	14	16	19	25	0
1980	49	74	16	13	11	13	24	0
1985	55	85	12	10	4	5	29	0

increasingly important fuel, and one with no greenhouse consequences, the relative importance of coal has grown even faster. The growth of electrical power in the economy is reflected in the much lower contribution of coal to energy consumption and carbon dioxide production in the industrial (Table 5) and the residential-commercial sector (Table 6).

TABLE 5

Relative Contributions of Major Energy Sources to Carbon Dioxide Produced in the Industrial Sector

	Coal		Natural Gas		Petroleum		Electrical Utilities	
	% Energy;	% CO_2	% Energy;	% CO_2	% Energy;	% CO_2	% Energy;	% CO_2
1975	13	20	30	26	29	36	28	18
1980	10	14	27	21	31	38	32	27
1985	10	16	26	20	28	32	36	32

TABLE 6

Relative Contributions of Major Energy Sources to Carbon Dioxide Produced in the Residential and Commercial Sectors

	Coal		Natural Gas		Petroleum		Electrical Utiliti	
	% Energy;	% CO_2	% Energy;	% CO_2	% Energy;	% CO_2	% Energy;	% CO_2
1975	0.9	1	32	27	16	20	51	52
1980	0.6	0.9	29	25	12	15	58	59
1985	0.7	1	26	23	10	12	63	64

Estimates of the release of greenhouse gases other than carbon dioxide by fuel type are not as readily available as for carbon dioxide. The Clean Air Act requires EPA to maintain inventories of emissions of specific criteria pollutants, including oxides of nitrogen (NO_x), oxides of sulfur (SO_x), carbon monoxide (CO), and volatile organic compounds (VOC). Oxides of nitrogen act directly as greenhouse gases, while the other criteria pollutants influence the concentrations of ozone and methane, two significant greenhouse gases. Increased levels of nitrous oxides and VOC heighten the atmospheric production of ozone. Greater amounts of carbon monoxide can lead to increased ozone levels, both through production processes and by lowering the concentration of hydroxyl (HO), a principal species that destroys both ozone and methane. Sulfur dioxide reacts with ozone to reduce concentrations of that greenhouse gas, but in the process produces sulfuric acid.

Over the last 10 years, regulations controlling automobile emissions have led to significant decreases in carbon monoxide emissions, and new sources performance standards have led to decreases in SO_x emissions while VOC and NO_x emissions have remained approximately level. (See Table 7.)

TABLE 7

Trends in Estimated Emissions of Climate Influencing Pollutants
(in millions of metric tons)

	1975	1980	1984
Carbon Monoxide (CO)	81	76	70
Oxides of Nitrogen (NO_x)	19	20	20
Volatile Organic Compounds (VOC)	23	23	21
Sulfur Dioxide (SO_2)	26	23	21

(Source: *National Air Quality and Emissions Trends Report*, EPA)

Highway vehicles are the major source of CO while both mobile and stationary sources are important in NO_x emissions. (See Table 8.)

TABLE 8

Emission of Criterial Pollutants by Source in 1981

	SO_x	NO_x	CO
Total (in metric tons)	22	21	74
Stationary Source (%)	79	45	7
Natural Gas	nil	10	nil
Fuel	11	4	1
Coal	68	31	6
Mobile Sources (%)	4	46	77
Highway Vehicles	-	36	69
Aircraft, Railroads, Other	-	10	8
Industrial Sources (%)	17	3	7
Other (%)	-	6	9

(Source: National Air Pollution Estimates, EPA, 1982)

Your third question is:

(3) **Are there opportunities to shift fuels in such a way to lessen the greenhouse effect?**

This question raises profound issues about this country and the world's future economic development. While, as you have heard this morning, there is wide agreement among scientists as to the reality of the greenhouse effect, there is much less agreement as to the timing of major

changes in climate and the consequences of warming. Despite uncertainties, I believe that action is required now, even though the uncertainties are real. We will never be fully confident in our predictions; more research will slowly reduce uncertainties but not eliminate them.

Slowing of climate change can come about through more efficient use of energy and through the substitution of less polluting fuels for those fuels, particularly coal, that result in high emissions of carbon dioxide and other trace gases. A move away from carbon fuel-based economies provides one alternative, whether stimulated by market forces or by government intervention, if anticipated climate changes become unacceptable. One candidate for an energy changeover is nuclear technology, but this alternative is far more threatening to much of the world's population than is climate change. The fact that many fears have no scientific basis is irrelevant; the fears are real.

A move away from carbon-based fuels could be stimulated by imposing a user charge on carbon dioxide released into the atmosphere. The carrying capacity of the atmosphere is treated both in capitalist and socialist societies as a free good. There are thus no economic incentives to use energy sources such as nuclear, solar, or natural gas that have less potential for changing climate. I recognize that the imposition of a user charge is unprecedented, but a charge of even one-tenth of a cent per pound of carbon dioxide emitted would raise 10 billion dollars, as well as

provide an economic incentive to use those fuels that have a lesser climatic impact. The past history of user charges has not been encouraging. During the early 1970s, I participated in preparing the Administration Proposal for a user charge on sulfur dioxide; that initiative died quickly despite its admitted virtues of economic efficiency. However, in view of the present talk of revenue raising measures such as a tax on imported oil, it would in my opinion be wise to consider a carbon dioxide user fee.

In the last Congress, several proposals were introduced to limit sulfur dioxide emissions in connection with the acid rain problem. Sulfur dioxide is only one of the criteria pollutants that influence climate change. In fact, if only sulfur dioxide were reduced, there might be an adverse effect on climate since ozone levels could rise. While this point is controversial, I do not think that there is any scientific disagreement as to the benefits of simultaneously reducing SO_x, CO, NO_x, and hydrocarbons. Thus, in view of the high degree of interdependencies among the chemical species in the atmosphere, I would support legislation designed to reduce simultaneously all four of the criteria pollutants, rather than concentrating on one or two, or even three alone.

I now turn to a number of less sweeping measures than user charges and massive reductions in sulfur dioxide. Each of the suggestions will help incrementally in slowing the buildup of greenhouse gases.

- Maintenance of a national 55 mph speed limit. Enforcement of speed limits is probably the most cost-effective means of encouraging conservation in the transportation sector. Higher speed traffic also leads to higher ozone levels as a result of greater NO_x and CO emissions.

- Maintenance of the EPA standards on mileage requirements for automobiles. Abandonment of these standards would lead to increased carbon dioxide emissions per mile traveled and would contribute to greater oxidant levels.

- Increase the use of natural gas. A number of steps can be taken to increase the burning of natural gas, the cleanest carbon-based fuel. These include the repeal of the constraints to natural gas use contained in the Power Plant and Industrial Fuel Use Act of 1978 and the disincentives to natural gas use set out in the Natural Gas Policy Act of 1978. The use of natural gas as a fuel for transportation should be encouraged, particularly for fleet vehicles. The highly successful experience with the use of compressed natural gas (CNG) for automobiles and trucks in New Zealand provides an excellent example of what can be done. Use of CNG vehicles in those urban areas which are in non-compliance with the ozone standard should be encouraged. For industrial applications, gas-fired cogeneration is highly energy efficient,

as well as attractive in terms of low emissions of greenhouse gases. Energy tax credits for such use would provide a powerful stimulus for an environmentally sound energy source.

These are examples of small steps that will help deal with the greenhouse problem. In the longer term, this problem can only be dealt with on an international basis, since all countries contribute to the alteration of the earth's atmosphere. We should continue international research efforts such as those sponsored by the World Meteorological Organization (WMO), and those undertaken by the United States and the Soviet Union under the bilateral Environmental Agreement. Beyond research, we should work within the Organization for Economic Cooperation and Development toward instituting a user charge system, perhaps coupled with regulations to limit greenhouse gases such as those that limit the use of chlorofluoromethanes (freons) here in the U.S. Only such international efforts can prevent the world's societies from irreversibly changing the character of our planet, possibly in ways that all people will recognize as undesirable.

APPENDIX

SCIENTIFIC BASIS FOR THE GREENHOUSE EFFECT

Introduction

Compared with the intense heat of Venus, or the stark day-night contrast of Mars and the moon, the earth possesses a relatively equitable climate that makes possible the existence of Homo sapiens and all their activities. The favorable nature of the earth's climate is made possible by the beneficial interactions of the oceans, atmosphere, and biosphere. The definition of climate is complex but a primary descriptor of climate is temperature. The temperature of the earth's atmosphere depends on the delicate balance between the incoming, short-wavelength radiation of the hot sun and the outgoing radiation of the much cooler earth.

If the atmosphere were stripped away, the average temperature of the earth's surface would be an inhospitable 35°C colder than it is today. The atmosphere provides a warming blanket for the surface through the action of certain constituents whose concentration is much smaller than that of the dominant nitrogen and oxygen. Water vapor, carbon dioxide (CO_2), and ozone (O_3) are the most important of these species, though a myriad of other constituents contribute to the warming.

The oceans play an important role in determining climate not only by providing a gigantic reservoir for water (and carbon dioxide) but also through their large thermal inertia. Without the stabilizing oceans, our climate would be much more subject to rapid change. The biosphere also serves as a source and sink for climate-controlling constituents of the atmosphere. By determining in part the reflective nature of the earth's surface, the biosphere also controls, in part, that fraction of the sun's radiation that is reflected back into space without interacting thermally with the surface and atmosphere.

Weather and climate are important determinants of a region's character and how a society develops. The day-to-day fluctuations of the atmosphere make up weather. By convention, normal climate is taken as a moving 30-year average of weather. The 30-year standard is an attempt to balance the practical limitation of data accumulation with statistical requirements for stable measures. Despite the artificiality of such definitions, it is clear that weather and climate influence a region's energy use, its growth of plants and animals, its means of transportation, its water supplies, its natural areas, its pattern of habitation; in brief, its infrastructure. A combination of temperature and availability of moisture determines whether vegetation is forest, prairie, tundra or desert, and also the ease with which society can adapt to natural stresses. The frequency of such extreme events as

tornadoes, hurricanes, floods, and droughts affects the habitability of a region and the investments required to moderate economic, physical, and social stresses created by weather and climate. The entire physical and economic infrastructure of a region is an adaptation to the prevailing climate, an adaptation developed over centuries.

Climate change refers to shifts in normal climate lasting over decades. Year-to-year events, such as several years of extremely dry or wet conditions, are variations in climate, not climate change, if they are within the expected statistical deviations for normal climate. Decades-long trends in regional climate, such as the gradual change of a tropical savanna to a desert, constitute climate change. Global climate change refers to shifts, generally in the same direction, over all parts of the planet. The Little Ice Age, dating from about 1500-1850 A.D., involved a global cooling with an extension of sea ice in both the northern and southern hemispheres. The Little Ice Age thus qualifies as climate change.

Global climate changes have had a profound effect on human history (Lamb, 1982). Only 18,000 years ago, a several-kilometer thick ice sheet covered much of Canada, northern United States, and northern Europe. During the period 8000-4000 years before the present (B.P.), conditions were warmer than today by perhaps as much as 1-2°C, with precipitation zones shifted northward. About 1000 years B.P.,

relatively warm temperatures allowed the Norse to cross the North Atlantic. With the Little Ice Age came temperatures a few tenths of a degree centigrade colder than today. Not only were temperatures lower but there was an increased variability in climate with numerous years of famine and plague well documented in Europe.

We now recognize that man's activities can bring about changes in climate in addition to those due to the natural fluctuations and long-term evolution of the atmosphere. Before 19th century industrialization, man's activities were of too small a scale and too low an intensity to alter weather or climate. With the mechanization of agriculture and the greatly enhanced use of carbon-based fuels, particularly coal, the situation changed. Both the burning of coal and the greater development of agriculture began the release of carbon that had been stored in the soil and rocks for thousands or millions of years. Once released, carbon forms atmospheric carbon dioxide and the composition of the atmosphere is changed, perhaps irreversibly. Of all of man's myriad activities, none has brought about as pervasive and large-scale an alteration as that of the composition of the atmosphere resulting from agriculture and energy use.

Though Tyndale (1861) recognized that slight changes in atmospheric composition could bring about climate variation, it was not until 1938 that Callendar showed that man, by burning carbon-based

fuels, was capable of changing the climate of the planet. The subject of anthropogenic climate change is thus only 50 years old. Intensive study began with the heightened interest in the environment during the late 1960s. The last decade has seen two major advances in understanding climate change. Carbon dioxide, once thought to be the sole culprit, is not alone in changing atmospheric thermal balance; other gases, taken together, are of comparable importance. Stated in another way, looking toward the future, the problem is twice as severe. The second discovery is that the earth's surface in the 1980s is 0.5°C warmer than it was during the 1880s. The change has not gone smoothly over the years, but despite the erratic course of earth's temperature, it is clearly moving in the direction of global warming in accord with theoretical expectations.

The Atmosphere as a Greenhouse

The hot surface of the sun radiates as a body having the equivalent temperature of 5800°K. The bulk of the radiation is in the visible wavelength region, 0.4-1.0 μm, where earth's atmospheric gases absorb only weakly. In contrast, the low temperature earth emits radiation at infrared wavelengths for which the atmosphere is highly absorbing, as is illustrated in Figure 1. In an oversimplified description, the atmosphere lets shorter wavelength radiation in but does not let the longer wavelength radiation out. By supposed analogy

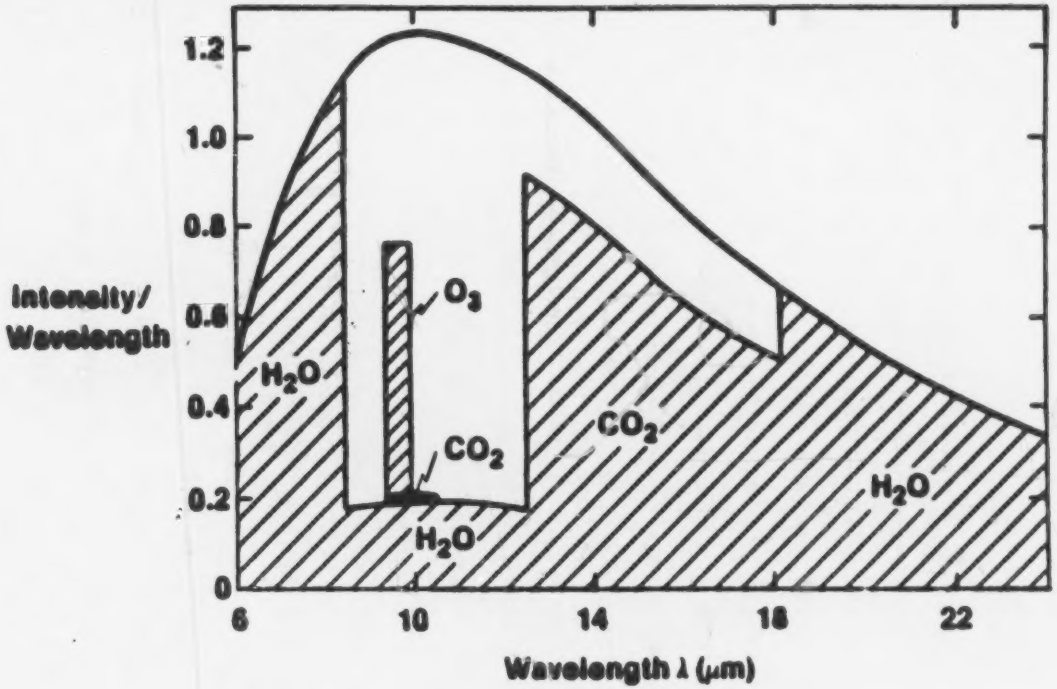

Figure 1. Absorption of Earth's Thermal Emissions. Thermal emissions of the earth's surface at a temperature of 290°K. The amount of emissions absorbed, and the relative values of absorptive gases are indicated by shaded areas. The figure illustrates why trace amounts of absorbers in the 8.5 to 12.5 μm (micron) region can be critically important in determining the thermal balance of the atmosphere.

with the behavior of panes of glass, the effect is called the greenhouse effect. In reality, greenhouses do not depend on trapping radiation for their warmth but rather inhibit cooling of the plants due to moving air; thus, thin plastic works just about as well as glass.

In the strongly absorbing infrared region, different molecular species are responsible for the opaqueness of the atmosphere at various wavelengths (see Fig. 1). Water molecules are strong absorbers over much of the region at which the earth radiates, 5-30 μm. However, water is a relatively weak absorber in the 8.5-18 μm interval which coincides with the region in which the intensity of the earth's outgoing radiation is at a maximum (see Fig. 1). The 12.5-18 μm region is blocked by the carbon dioxide now in the atmosphere. The addition of further carbon dioxide will not affect the 12.5-18 μm region of outgoing radiation. The 8.5-12.5 μm interval is relatively transparent so that energy radiated at these wavelengths flows more freely into space. However, transparency of the 8.5-12.5 μm "window" is reduced in part by strong absorption by ozone at 9.6 μm and weaker absorption by CO_2, as shown in Figure 1. Increasing concentrations of ozone and carbon dioxide thus reduce the transparency of the window leading to a warming of the atmosphere. In addition to molecular species, clouds and particulate matter (aerosols) can contribute to the trapping.

Calculating the combined radiation-trapping effect of a variety of molecular species is a complex task. The contributions of individual absorbers do not add linearly, in part because molecules differ greatly in their capacity to absorb radiation and also because the regions which the species block off overlap. In rough terms, CO_2 currently accounts for 12% of the trapped radiation, but if all other absorbers were removed, CO_2 would trap three times as much energy. Similarly, clouds currently trap 14% of the radiation, but they would trap 50% of the currently absorbed radiation if all other absorbers were removed. The complexities of the radiative processes are further underlined by noting that the upper layers of the atmosphere leak relatively more radiation into space than they trap, so that additional carbon dioxide leads to atmospheric cooling rather than warming at layers above 20 km.

Over the last decade, it has been recognized that a variety of species have strong infrared absorption modes that lie in the window of transparency (Ramanathan, 1975; Chamberlain et al., 1982). In some cases, the concentrations required to affect the radiative balance are minute compared with that of carbon dioxide, due to the strength of the absorption bands. Trace species that are capable of affecting the radiative balance include nitrous oxide (N_2O), methane (CH_4), and freons (CCl_3F, CCl_2F_2), as well as ozone. All of these trace species

are increasing in concentration due to agricultural and industrial activity, and these increases add to the blanketing capacity of the atmosphere.

Changes in Atmospheric Carbon Dioxide Concentration in Historical Times

Remarkably, carbon dioxide was the first constituent of the earth's atmosphere to be identified. Joseph Black published the discovery during 1754 in a University of Edinburgh thesis. By 1870, quantitative measurements developed which compare in precision with today's measurements. Interpretation of early observations is made difficult, not by inadequacies in analytical chemistry but because they were not undertaken to measure changes in the composition of the atmosphere. Sampling for this purpose is complicated owing to the extreme danger of contamination from, for example, the observer's breath. While numerous observations of the CO_2 content of the atmosphere are reported in the literature during the period 1870-1910, their interpretation remains ambiguous. After about 1910, few reports are available since the composition of the atmosphere was considered known and fixed and analytical chemists pursued other interests.

The situation changed dramatically in 1958 when C. D. Keeling of the Scripps Institution of Oceanography, at the suggestion of Roger Revelle, began a series of painstaking measurements of CO_2 concentration on a remote site at what is now the Mauna Loa Observatory in

Hawaii. His observations, continued to the present, show an exponential growth of atmospheric carbon dioxide on which a periodic seasonal fluctuation is superimposed (Keeling et al., 1984) (see Fig. 2). The seasonal variation follows the biospheric uptake of CO_2 during the growing season and its discharge during winter. Keeling also established and maintained an observing regimen at the South Pole. The Antarctic observations show a similar exponential growth but a more diminished seasonal variation (see Fig. 3). Since the atmosphere at the South Pole is well removed from biological activity, the smaller seasonal fluctuations are expected. Keeling's observations have been duplicated at other stations in various parts of the world over shorter periods of time. In all sets of observations, the exponential increase is clear, though the amplitude of the seasonal terms varies with latitude. For example, a 20-year long record taken from observations on a weather ship in the northeast Pacific (50°N, 145°W) shows greater seasonal fluctuations than those seen at Mauna Loa; the amplitude of these fluctuations reflects the strong seasonal dependence of the mid-latitude northern hemisphere biological activity.

The exponential growth in atmospheric CO_2 concentration correlates with the release of CO_2 by the burning of oil, coal, gas, and wood. Since 1945, the injection of carbon into the atmosphere by fuel combustion appears to be exponential, with a slowing in growth

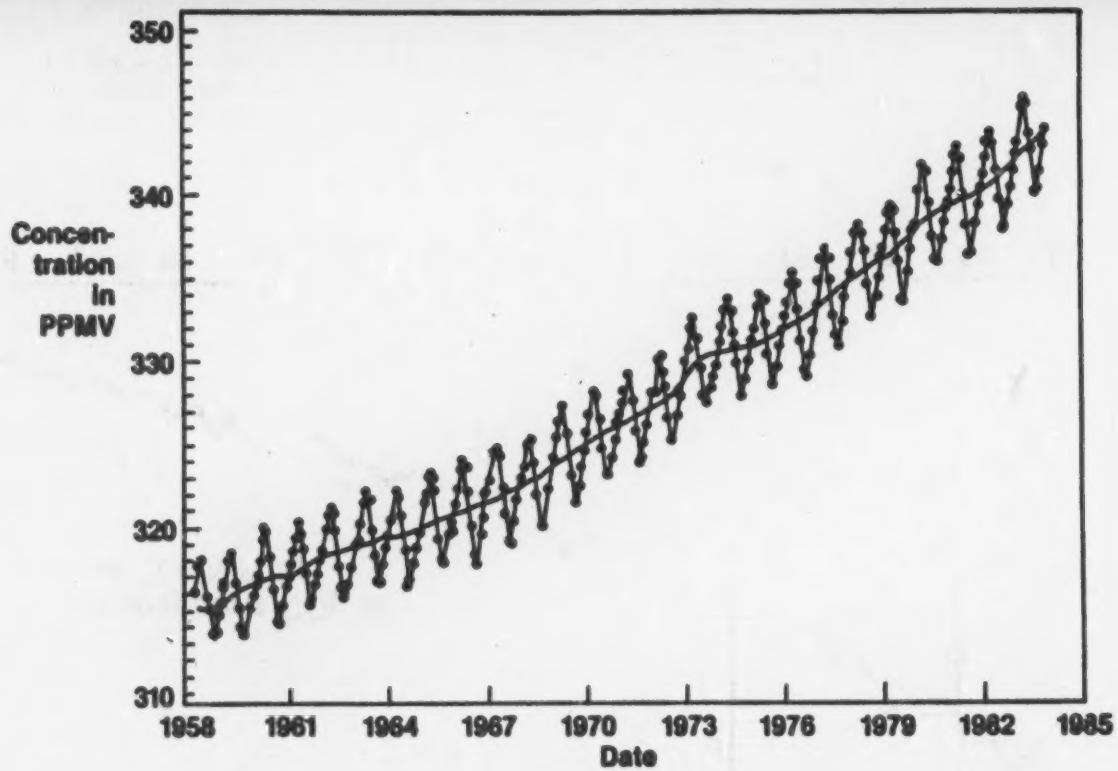

Figure 2. Atmospheric CO_2 Concentrations at Mauna Loa Observatory, Hawaii. Measured amounts show seasonal fluctuations, primarily of biological origin, superimposed on an exponential growth (Keeling, 1984).

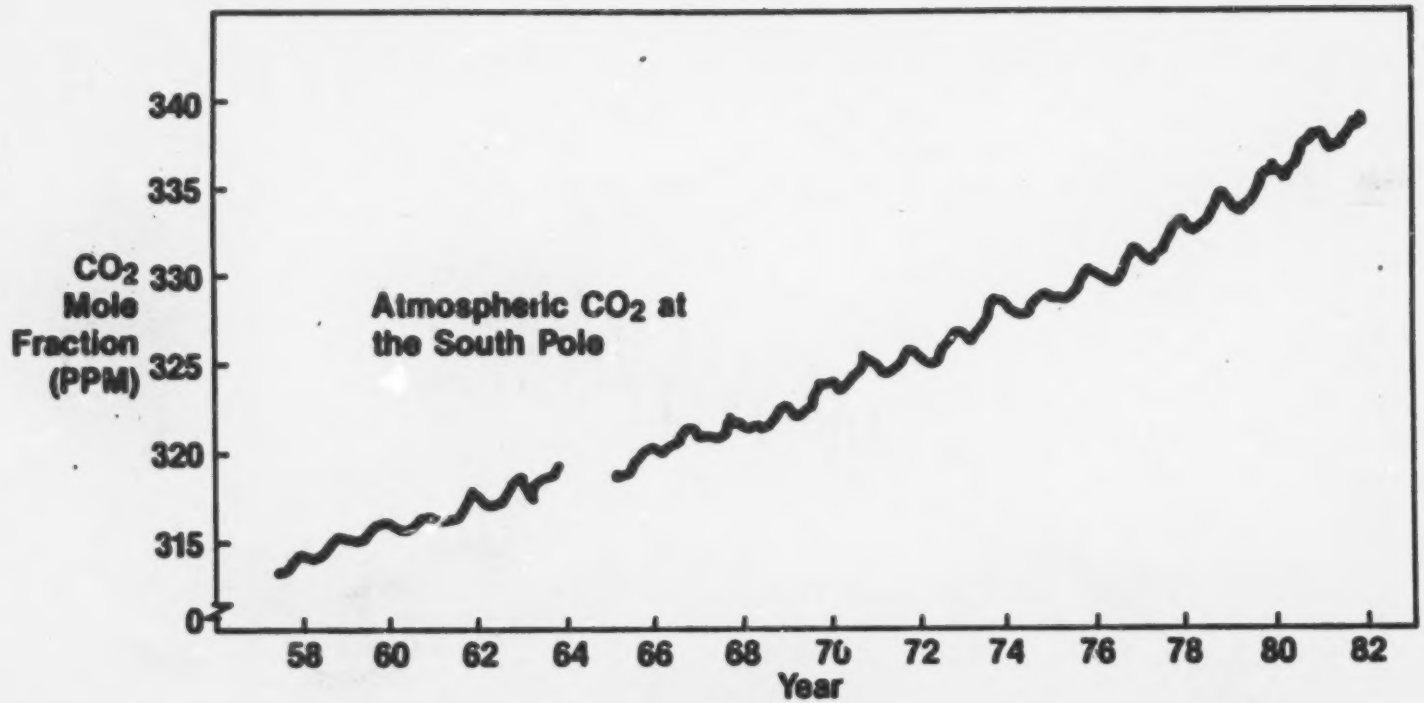

Figure 3. Trend in measured concentration shows the amplitude of seasonal fluctuations to be much less than at Mauna Loa because of the South Pole's remoteness from heavy biological activity.

following the 1973 explosion in energy prices (see Fig. 4). Exponential fits to the Mauna Loa and South Pole bracket the increase in carbon-based fuel use with the following exponential doubling times:

Mauna Loa	26.6 years
Fuels	23.9 years
South Pole	21.9 years

While the growth in atmospheric CO_2 parallels the release of carbon through energy use, the overall carbon budget is not well understood. The observed increase in atmospheric CO_2 accounts for only about half the carbon released through energy and industrial uses. Oceans are generally assumed to be a major sink for CO_2. While numerous models have been constructed to mimic ocean-wide diffusive and convective exchange processes, the ocean's capacity to remove CO_2 from the atmosphere over times on the order of decades remains largely uncertain. The carbon balance mystery is deepened by inadequate data on the net contribution of biospheric processes to the atmospheric carbon burden. Destruction of forest cover and cultivation of new land provides a source of atmospheric CO_2, but stronger growth in the many plants stimulated by increased CO_2 concentration should lead to greater biological productivity, and thus lead the biosphere to serve as a sink for CO_2. Both the sources and sinks

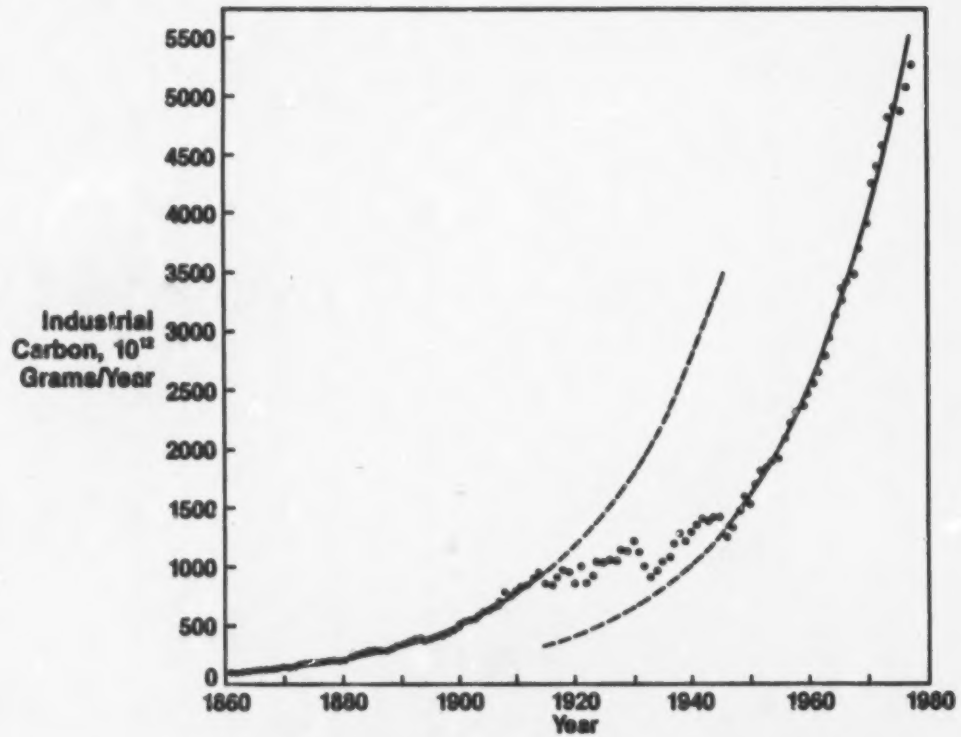

Figure 4. Anthropogenic CO_2 Production. The rate of production of carbon dioxide by man's activities (after Keeling, 1984). Units are 10^{12} g yr^{-1}. The major deviations from exponential growth between 1914 and 1945 reflect the effects of the two World Wars and the worldwide economic chaos between the wars.

associated with the biosphere are large numbers so that the net impact, being the difference of these large numbers, is most uncertain.

Estimates of future atmospheric carbon dioxide levels are clouded by questions regarding the overall carbon budget. A rough guess is provided by the observation that historically, about half the fossil-fuel carbon placed in the atmosphere remains there. More refined estimates will require a better definition of the role of the oceans and biosphere in the carbon cycle. Since oxygen is also removed from the atmosphere during the formation of CO_2, long-term measurements of the oxygen content of the atmosphere may be required to sort out the various sinks and sources for carbon.

The concentration of CO_2 in the atmosphere was about 315 ppm by volume when Keeling began his observations in 1958. During the period 1958-1986, CO_2 concentration increased by about 30 ppm, or 9.5% in 28 years. Central to understanding the total impact of intensive agriculture and energy use on the present CO_2 concentration is to establish the concentration 100 years ago, when these activities were just beginning. There are a number of ways to obtain a pre-industrial value. The first is to assume that conditions prevailing over the last 30 years held during the preceding 70. If one-half the carbon released in combustion remains in the atmosphere and all other sources

and sinks are relatively constant, then the concentration of CO_2 in the atmosphere during 1890 was about 293 ppm. Two ways of checking this value are available--analysis of air trapped in glaciers, and a careful reanalysis of the older observations.

When snow is transformed into ice during glacier growth, air is trapped in the intergrain spaces. The air remains in the airtight glacial ice as the glacier continues to grow. Chemical analysis of this air provides an estimate of the CO_2 content of the atmosphere at the time the air was encased. A number of difficulties lessen the value of such determinations. The time at which a particular layer of ice was laid down is difficult to estimate. The rate of snow accumulation affects the quantity of air that is trapped. The seasonal melting of snow may incorporate new air, leading to confusion. Despite these uncertainties, the values obtained from analysis of the most favorable samples indicate an atmospheric CO_2 concentration in 1890 of between 280 and 295 ppm (Raynaud and Barrola, 1985). These values are in general agreement with the value obtained by extrapolating current CO_2 concentration backward, assuming constant relative sources and sinks of CO_2.

From and Keeling (1986) have carried out a detailed reexamination of early observations of CO_2 concentrations, particularly those made by Callendar, the discoverer of the significance of anthropogenic CO_2. Among the criteria From and Keeling used was whether early

observations showed a seasonal cycle in accord with modern observations. The result of their analysis is that the mean annual concentration of atmospheric CO_2 circa 1880, in uncontaminated air at 50°N latitude, was 292 ppm. This value is consistent with backward extrapolation of current values as well as estimates derived from glacial air samples.

Historical observations coupled with extremely careful modern measurement show that the CO_2 concentration of the atmosphere has increased from about 290 ppm to 345 ppm in 100 years, or 19%. Future concentrations of CO_2 are difficult to estimate since they depend on unknown energy use rates, mixtures of fuels, patterns of deforestation and agriculture, and uptake of CO_2 by the oceans and atmosphere. Uncertainties in future CO_2 levels due to uncertainties in the carbon cycle may be small if past behavior provides a reliable clue; if this is the case, then about one-half of the CO_2 produced by fossil fuel combustion ends up in the atmosphere. There remains the difficult task of projecting energy use decades into the future if we are to determine the atmosphere of tomorrow and its associated climate.

Trends in Other Warming Gases

Historical trends of other anthropogenically produced gases, including methane, nitrous oxides, and ozone are poorly known, in part because recognition of their significance to climate change has come

only in the last decade. Freons present a different story, they are manufactured gases and came into major use only during the 1960s. Production data are readily available, except for eastern bloc countries and China, and since freons are very long-lived in the atmosphere, production data alone provide a good guide to their trends since introduction during the 1960s.

Anthropogenic sources of methane include direct emissions from the production and transportation of natural gas and from the burning of biomass. Cultivation of rice paddies and the raising of ruminant animals can also lead to increased methane production. Interpretation of the observed methane concentration is complicated in that a number of atmospheric chemical reactions involving methane and other constituents, such as carbon monoxide, can lead to increases or decreases in atmospheric methane concentration. Further, emissions of carbon monoxide are increasing as the use of fossil fuels increases. Observations made over the past decade at a number of stations show that the CH_4 concentration is increasing at about 2% per year (Khalil and Rasmussen, 1983, 1985). Whether the increase is due to greater emissions or heightened removal of constituents in the atmosphere that would otherwise react with methane is not clear. As in the case of carbon dioxide, data on past methane concentrations can be obtained from the analysis of trapped air in glaciers. These data suggest a

long-term exponential growth with an exponential doubling time of 46 years (see Fig. 5). Given the large uncertainties in interpretation of the air bubble data, the close fit of observation with the exponential fit should be viewed with some skepticism, particularly since the sources and sinks for methane are not well understood.

While the overall residence time of methane in the atmosphere is relatively short, about 6 years, nitrous oxide is much less reactive and has a residence time of over 100 years. The current annual rate of increase of N_2O is estimated at 0.2% per year (Weiss, 1981). This value is based on sparse observations; historical data are not available. A number of processes add N_2O to the atmosphere. Combustion of fuel produces N_2O, as does the breakdown of ammonia used as a fertilizer. Disposal of human and animal waste strongly stimulate nitrification, and waste disposal is another source of atmospheric N_2O.

Freons came into major use during the 1960s and initially showed a high, 10-15% per year growth. Due both to the imposition of environmentally based regulation and to the downturn in economic growth, the rate of freon use slowed during the late 1970s and early 1980s, but has resumed more recently (Cunnold et al., 1983a, 1983b). Most recent data indicate a growth rate for $CFCl_3$ of 9.0 parts per trillion (ppt) per year and for CF_2Cl_2 of 15.3 ppt per year (Cunnold

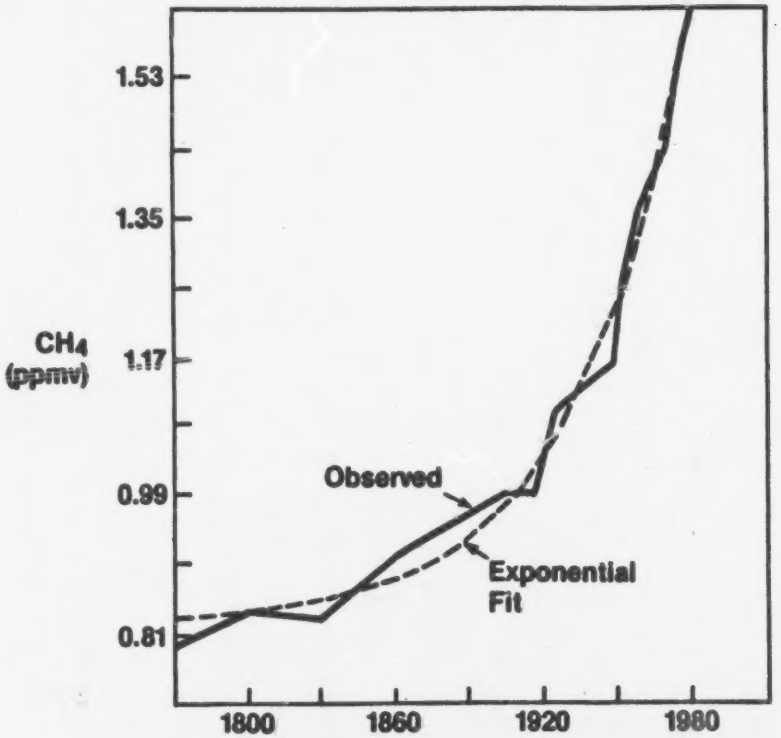

Figure 5. Estimated Variation of Atmospheric Methane Concentrations. Data prior to 1960 taken from measurements of methane contained within air bubbles in ice cores (Stauffer et al., 1985).

et al., 1986). These values correspond to percentage growth rates for both $CFCl_3$ and CF_2Cl_2 of 5.1% per year. The observed atmospheric concentrations and growth rates are in good agreement with published production data (Cunnold et al., 1986).

A variety of observations show that the tropospheric concentration of ozone is increasing, even though the stratospheric concentration may be decreasing as a result of complex chemical reactions with freons stimulated by ultraviolet radiation. While the total amount of ozone in the troposphere is small compared with stratospheric ozone, it is important in considering the energy balance of the atmosphere. At the lower levels of the atmosphere, ozone is at higher pressures and its absorption of outgoing infrared radiation is very much more effective than higher level ozone. Measurements from a rural site on an island in the Baltic show an increase in ozone of about 60% since the 1950s (see Fig. 6, Warmbt, 1979). Similar trends have been observed at stations in the Alps, North America, and Japan, though local atmospheric conditions complicate interpretation of the data (Logan, 1985).

As in the case of methane and nitrous oxide, the sources and sinks of ozone are not thoroughly understood. Ozone forms photochemically in urban smog but can also form in rural atmospheres if hydrocarbons are present. Free hydroxyl radical (HO) is a

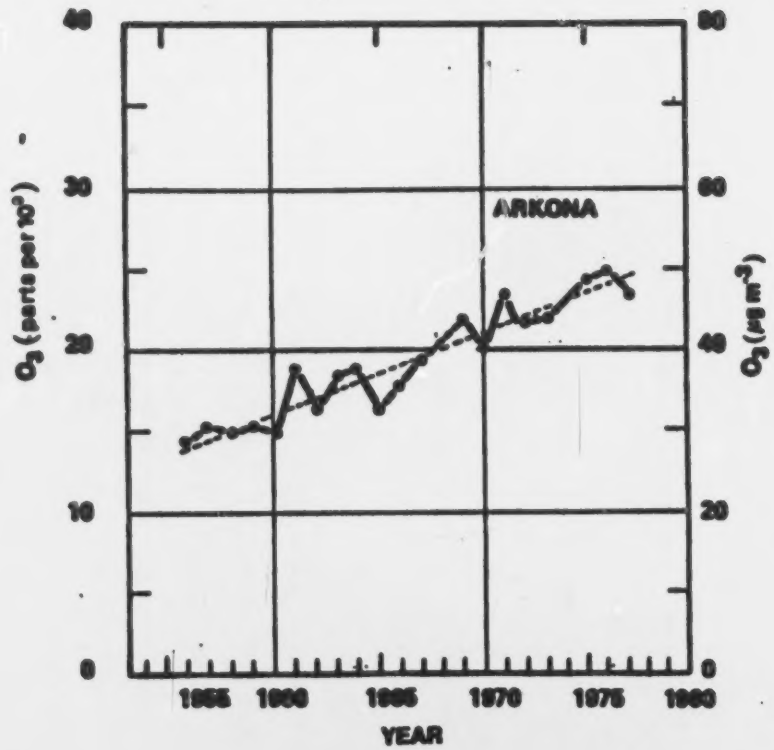

Figure 6. Trend in Mean Annual Ozone Concentration at Rügen, German Democratic Republic. Observing station is located at a rural site on an island in the Baltic, well removed from any industrial activity (after Warmbt, 1979).

principal sink for ozone, but HO may be taken up by methane and carbon monoxide with which it also reacts. Increasing concentrations of CH_4 and CO will lead to increased tropospheric ozone. A principal source of carbon monoxide is the automobile. Increased automobile traffic leads to increased levels of hydrocarbons and nitrogen oxides--sources of ozone, and of carbon monoxide which is a sink for hydroxyl. The combination of higher source concentrations and lower sink (hydroxyl) concentration leads to higher ozone levels and increased atmospheric warming.

While the importance of methane, freons, nitrous oxide, and ozone in producing a greenhouse effect is well established, their past and future concentrations are much less certain. All are the result, either directly or indirectly, of energy use and/or industrial activity. Thus, all of these radiatively active species can be expected to increase significantly over the next 50 years.

Models of Climate Change Due to Greenhouse Gases

The task of predicting future climate change is extremely complex. Given the relative stability of climate evidenced by the observed slow rate of climate change over geologic time, it is tempting to seek a past climate that would provide an analogue to present and future climates. Increasingly detailed data are available on conditions prevailing during the Holocene climatic optimum

(5000-6000 years B.P.), the last major interglacial period (about 125,000 years B.P.), and the Pliocene warming (3-4 million years B.P.). During these intervals, the mean temperature was warmer than today by about 1°C, 2°C, and 3-4°C. But these times are poor analogues to future climatic change. Past changes took place slowly, on time scales of at least thousands of years; their cause is not known. Today, changes in the composition of the atmosphere are taking place in decades, the basic radiative characteristics of present constituents are nonlinear, and changes in composition are taking place at an exponential rate. While past climates may provide guidance as to the possible future evolution of warm periods, they yield less information as to current trends. An alternative to extrapolating from historical climates is to construct artificial ones from mathematical models.

Over the years, a hierarchy of climate models has been developed to estimate climate change. At one end of the scale are energy balance models which are based on conservation of energy and, in their simplest form, treat the entire earth's surface as having a single temperature. Their advantage is their simplicity; the only equation that enters is that of conservation of energy, unknown quantities need not be guessed at and the calculation does not require a computer. The disadvantage of such energy balance models is that only average

temperature changes are predicted; this failing must be weighed against the advantages of parsimony of assumptions and simplicity of calculations. At the other end of the scale of complexity are the Global Circulation Models (GCM). These are three dimensional representations of the atmosphere that explicitly include equations for conservation of mass, water vapor, energy, and zonal and meridional components of momentum. In their most detailed form, GCMs are based on a 500 km grid size in the numerical approximation to horizontal motions, with up to nine layers in the vertical direction. As a result, on the order of 20,000 grid points are required in approximating the continuous atmosphere over the earth's surface. In total, the calculation requires the treatment of about 200,000 equations, with each equation requiring extensive calculations. The calculation of the evolution, over time, of this large set of equations strains the largest available computers, particularly when careful attention is paid to delicate issues of numerical stability of the finite difference approximation to the underlying partial differential equations.

Comprehensive three-dimensional models are designed to provide estimates of those parameters of climate change most critical to society, the regional, seasonal and diurnal distribution of temperature, soil moisture, and surface runoff. This task is made

complicated by the requirement that valid approximations be developed for the many processes taking place over the time and space scales of interest. For example, there is a need to represent clouds and cloud systems which typically have dimensions of one to ten kilometers, much less than the resolving power of the numerical grid of 500 km. Major difficulties arise in parameterizing cloud coverage and cloud heights because these quantities vary on scales less than the numerical resolution. Because clouds are important in calculating the distribution of radiative energy, the manner in which the approximations are made is critical, and various climate modeling groups use somewhat different approaches. Similar difficulties in parameterization arise in treating soil moisture, air-sea interaction, topography, biological activity, etc.

Among models of complexity intermediate to the energy balance and GCMs are the radiative-convective models (RCM) (Ramanathan and Coakley, 1978). These treat the vertical structure of a global average atmosphere assuming bouyantly stable stratification. RCMs divide the vertical atmosphere into several layers but do not deal with horizontal motions. RCMs are particularly well suited to a detailed evaluation of the radiative effects of CO_2 and trace gases and aerosols, as well as the chemical reactions among radiatively active species.

A conventional means of comparing models is to calculate the average surface temperature that would result from doubling the

atmospheric CO_2 concentration from 330 ppm to 660 ppm. Early estimates made during the late 1960s predicted that a doubled CO_2 content should raise the average temperature 1.5-3°C (Manabe and Wetherald, 1967). More than 100 independent estimates of average surface temperature increase have since been made using energy balance, RCMs and GCMs. Almost all of these estimates lie in the range 1.5-4.5°C, with values near 3°C tending to be favored (Schlesinger and Mitchell, 1985).

Intercomparisons of GCM simulations of CO_2-induced climate change show that while there is general agreement as to the surface temperature change, there is much less agreement in the geographical distribution of temperature changes, and sometimes large disagreement on geographical distribution of soil moisture and runoff. This state of affairs is not surprising in that the calculation of temperature depends primarily on energy conservation, and all models incorporate this basic feature. Geographic distributions of various quantities, particularly those involving precipitation, will depend sensitively on the details of the parameterization of those quantities that are either or both poorly understood or inadequately resolved in the numerical approximations.

The large heat-retaining capacity of the oceans coupled with the mixing processes in their upper layers are the main factors providing

thermal inertia to the climate system. This thermal inertia slows down climate change due to anthropogenic changes in atmospheric composition. GCMs can be used to calculate the delay of the equilibrium response of the atmosphere to changes in atmospheric composition. Results from available models suggest that thermal storage and mixing in the ocean reservoirs cause a lag in the warming of 10 to 20 years. If an exponential change of atmospheric CO_2 composition with a doubling time of 20 years leads to an equilibrium warming of 1°C, then the observed response would only be 0.7 ± 0.2°C (Hoffert and Flannery, 1985). The large uncertainty arises because of incomplete knowledge of the formation of bottom waters and of the mixing processes in the wind-stirred upper layers of the oceans, particularly the Artic and Antartic pumps involving thermohaline circulations.

Over the past 100 years, the carbon dioxide content has increased by about 20%. A range of model calculations suggests that the corresponding equilibrium temperature rise should be 0.5-1.0°C. If this is corrected for the effects of the thermal inertia of the oceans, the changing composition of the atmosphere should have produced a warming of 0.35-0.7°C superimposed on the natural fluctuations of the atmosphere. Since natural variations associated with El Niño and volcanic eruptions bring about short-term changes on the order of a few tenths of a degree, the roughly half-degree increase of the longer-term trend must be extracted by careful statistical analysis.

Observed Climate Changes

In addition to noting the anthropogenic warming, Callendar (1938, 1949, 1961) attempted to estimate expected changes in climate, particularly temperature shifts. As interest in the subject has increased, larger computer-based data sets have been developed. The principal problem in analyzing the data is one of sampling. Data are highly biased toward land in the northern hemisphere. Since oceans cover more than 70% of the earth's surface, this bias is large. Many land-based observing stations are located near urban sites. This location itself introduces a further bias since as the urban region grows, more energy is consumed and there is a local warming trend. Inconsistencies in data collection stem from changes in both observing instruments and calibration practices. Observing stations have been relocated, and the shelter used to house the thermometer may have been altered. These are just a few of the difficulties that must be overcome in order to construct a homogeneous data set. While all of these considerations are important, the principal deficiency in the past has been the lack of data over the oceans.

Jones et al. (1982, 1986a) have carried out a detailed analysis of land-based observations. The data have been carefully examined to detect and correct for nonclimate errors that result from station shifts, urban development, and changes in instrumentation. Folland

et al. (1984) and Jones et al. (1986b) have attempted the daunting task of using sea surface temperatures (SST) and marine air temperatures (MAT) recorded by ships at sea to obtain ocean temperature estimates. For MAT, there are problems, including a great diversity of instruments and practices as well as varying placement of the thermometers on ships. SST are determined both from bucket measurements and from water intake measurements, after the conversion from sail to steam. Jones et al. (1986b) attempt to calibrate the SST and MAT observations by first carrying out a correlation of MAT with nearby land for 15 regions of the world. The corrected MAT for various time periods are then used to calibrate the SST. The number of observations is large; Folland et al. (1984) used a British data set of 46 million SST observations. Jones et al. (1986b) used that set and the Comprehensive Ocean Atmosphere Data Set of the National Oceanic and Atmospheric Administration comprising some 63 million SST observations.

The results of the analysis of Jones et al. (1986b) are summarized in Figure 6. In judging the results shown, it should be recalled that spatial coverage is at best 75% and, more importantly, the coverage changes with time. Coverage before 1900 is less than 30%, with the northern hemisphere always much better represented than the southern hemisphere. In particular, the ocean south of 45°S and the whole southeastern Pacific are underrepresented.

The curve in Figure 7 shows a long-term warming trend. The magnitude of the warming agrees with theory; it is about 0.5°C over the last 100 years. In view of the heightened interest in long-term climatic change, the question naturally arises as to whether this trend would have been noticed if theory had not predicted that it should be there. I was convinced of the warming long before the detailed analysis of the records were available. I had observed that the snouts of the glaciers on the Alps on the South Island of New Zealand had moved from sea level to high up the mountain between 1900 and the present. New Zealand, having a relatively isolated geographical setting in the ocean, was more likely to capture longer-term trends in climate than glaciers in more continental regions. But glaciers, even on an isolated island, may not well serve as a surrogate for overall climate change. Since theoretical predictions of a one-half degree warming preceded the statistical analysis of historical observation, critics undoubtedly will question the reality of the derived warming even though the statistical base for the inference is strong.

The record of the warming trend shown in Figure 7 has several interesting features. The three warmest years were 1980, 1981, and 1983. Five of the nine warmest years in the 134-year record occurred after 1978. However, there remain puzzles. For the 40-year period

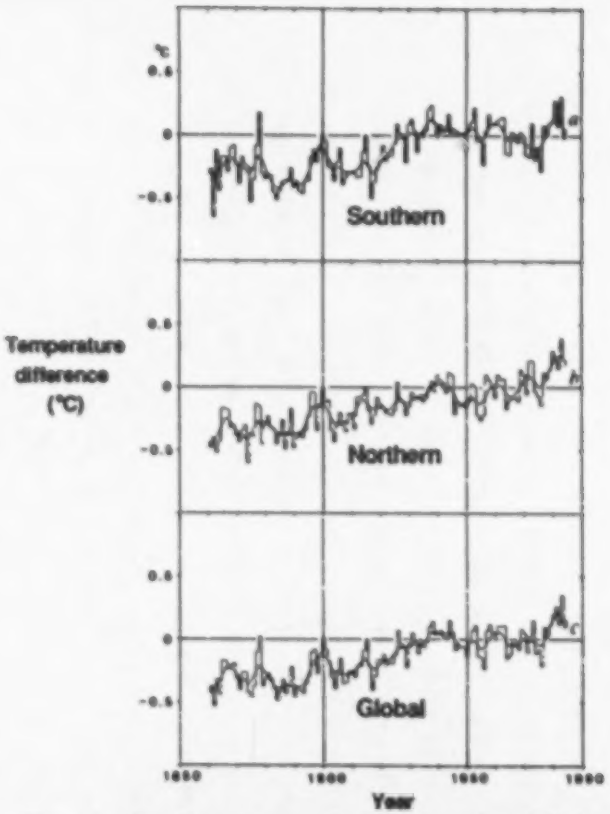

Figure 7. Annual mean temperature variations since 1861 (Jones et al., 1986b). Global change portrayed in curve c, northern hemisphere in curve a, and southern hemisphere in curve b.

between the mid-1930s and the mid-1970s the average temperature remained approximately stable at a time the exponential change in atmospheric composition should have produced an increased rate of warming. The increase in temperature between 1905 and about 1930 is high when compared to the expected increase. Thus, while the overall change in temperature is in the right direction and of the correct magnitude, a number of features of the observed warming are inconsistent with those expected from the greenhouse effect.

Future Greenhouse Warming

Projections of future warming are uncertain since future levels of use of carbon-based fuels are not known. The contemporary budgets of methane and nitrous oxides are not known, so projections of the contribution of these gases to future climatic shifts are even more uncertain than that of CO_2. However, over a relatively short interval of 50 years, 1980 to 2030, limits can be placed on expected climate variations on the assumption that there will be no radical shifts in the world's agricultural-industrial base. Ramanathan et al. (1985), using a radiative-convective model, have calculated an equilibrium warming of 1.5°C between 1980 and 2030, assuming a stable projection of current energy use. A little less than half of the projected increase is due to CO_2, the remaining increase is due to the other radiatively active gases. If the thermal inertia estimate of about 0.7 of the

theoretical warming holds, then the expected warming during the next 50 years is about 1°C, or twice that shown for the interval 1880-1980. The total warming over the 150-year period ending in 2030 of 1.5°C would be equal to or larger than that estimated as taking place during the Holocene, 5000 to 6000 years ago.

Using the simpler energy budget model, I have calculated a comparable temperature change (MacDonald, 1985). The assumed increases in the warming gases are shown in Table 1. Also included is carbon monoxide, which is an infrared absorber but whose concentration influences the abundance of methane and ozone. The calculated equilibrium surface warming is 1.8-2.2°C, as indicated in Table 2. This corresponds to an actual warming of 1.3-1.5°C, if current estimates of the thermal lag of the oceans are appropriate. The contribution to the warming of species other than CO_2 is 80-120% of the CO_2 warming, with ozone and methane being the principal other contributors. The major difference between these estimates and those of Ramanathan et al., other than the model basis, is that they anticipate a significantly greater contribution of freons to the warming (0.44°C), and lower contributions from ozone and methane. The lower contribution from ozone is due to Ramanathan et al.'s estimate of only a 12.5% growth in 50 years, which seems low when compared with recent trends.

Table 1

Changes in Concentration of Radiative Active Gases
for the Period 1980-2030

Species	Residence Time (Years)	1980 Mixing Ratio (ppbv)	Estimated 2030 Mixing Ratio (ppbv)
CO_2	2	340×10^3	450×10^3
N_2O	120	300	350-450
CH_4	7-8	1650	2500-3000
CCl_2F_2	110	0.30	0.6-1.2
CCl_3F	65	0.18	0.5-1.0
O_3 (troposphere)	0.1-0.3	20-70	30-100
CO	0.3	90	100-200

Table 2

Surface Warming Due to Change
in Atmospheric Composition, 1980-2030 (see Table 1)

Component	ΔT_S in °K
CO_2	1.0
O_3 (Troposphere)	0.2 - 0.4
CH_4	0.3 - 0.4
N_2O	0.2
$CFCl_3$ and CF_2Cl_2	0.1 - 0.2
Total	1.8 - 2.2

While the magnitudes of future sources and sinks of radiatively active species other than CO_2 are uncertain, it appears that the contribution of these gases to future warming can be as great or greater than that due to CO_2. The average global temperature in the year 2030 should be 1-1.5°C warmer than today. The climate in this regime will differ markedly from that we have become accustomed to.

Conclusions

Despite the many uncertainties in future energy use, carbon cycle evolution, and production of trace gases, it appears highly probable that over the next 50 years anthropogenic activities will warm the earth's surface by 1-1.5°C. This warming will be superimposed on the half-degree warming of the last 100 years. These changes are larger than those that can be anticipated from natural variations and are of the same order or larger than those associated with the Holocene warming 6000 years ago. If GCMs and previous climates are any guide, it is likely that the effects will be noted first at high latitudes. There will be a tendency toward lower precipitation and soil moisture in the mid-continent regions of North America and Eurasia, with more frequent, extended droughts. The warming may be accompanied by much increased climatic variability, with heightened frequency of extremes.

Much current thinking about the greenhouse effect assumes that society will adapt incrementally to change, even if the changes involve heightened sea level and droughts in the "food basket" areas

of North America and Eurasia. These assumptions are not convincing. Infrastructures of society such as water supplies, transportation nets, and land use patterns have evolved over centuries in response to prevailing climate. Significant changes in climate over decades will exert profound disruptive forces on the balance of infrastructures. The prevailing market economies in much of the world adjust to alterations in supply and demand through adjustments in price. The intangibles of climate are not readily quantified in conventional market terms; they are one of the externalities with which markets find so hard to deal.

A move away from carbon fuel-based economies, whether stimulated by market forces or government intervention, provides one alternative, if predictable climate changes become unacceptable. A candidate energy technology is nuclear, but this alternative poses far greater fears to much of the world's population than does climate change. Whether such fears are justified is irrelevant; the perception of dangers from the operation of nuclear power plants and storage of waste is real.

Conservative alternatives to that of blind belief in incremental adjustment are preparation of the way for alternative energy sources, including nuclear and renewable sources, as well as increasing overall energy efficiency. While climate change may be acceptable in the short term, it is not clear that it will be in the longer term.

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STATEMENT OF

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BEFORE THE
SENATE SUBCOMMITTEES
ON ENVIRONMENTAL POLLUTION
AND TOXIC SUBSTANCES &
ENVIRONMENTAL OVERSIGHT

HEARING ON THE GREENHOUSE EFFECT
AND OZONE DEPLETION

JANUARY 28, 1987

This hearing addresses one of the most difficult challenges yet faced by mankind -- the potential radical change in climate due to the accumulation of greenhouse gases. We commend the Committee for scheduling this hearing so early in the 100th Congress, as befits the importance of the issue.

In two hearings in the last Congress, this Committee reviewed in some detail the risks of accumulating greenhouse gases in the atmosphere and the related problem of ozone depletion. Distinguished scientists described possible temperature extremes in U.S. cities; devastation of forests and plant life; widespread coastal damage due to sea level rise; and radical changes in the timing and distribution of rainfall, with untold consequences for agriculture. These changes, they warned, could occur in sharp steps and without warning.

In our earlier testimony, WRI stressed that serious analysis of policy options for responding to the greenhouse problem is long overdue. While continued and expanded research is needed, action is also required because the very serious effects of a warming will be upon us before we fully understand all the whys and wherefores. We do know that what we do now - or fail to do- will have a great effect on the rate of growth in emissions of greenhouse gases, delaying or accelerating the onset of changes that, once begun, cannot be reversed.

My testimony today is addressed to the importance of incorporating the greenhouse problem in policy decisions being made today. The first part reviews the chemical and economic linkages between the greenhouse effect, ozone depletion, and air

pollution. As a result, policies being devised for the latter problems must be sensitive to the greenhouse effect as well. In the second part, I will review the results of a recent WRI study of the effect of different emissions rates on the timing of global warming. This study demonstrates that public and private choices before us today and in the next few decades could delay the commitment to a global warming equivalent to doubling the pre-industrial level of CO_2 by as much as 60 years -- time likely to be invaluable for developing longer term solutions.

In the final part of my testimony, I will outline some possible strategies to help buy time and avert possible catastrophe. While the analysis necessary to describe global policies fully responsive to the problem remains to be done, a surprising amount can be accomplished now. In particular, the technological opportunities for reducing emissions of carbon dioxide from fossil fuel combustion through increased energy efficiency are enormous and could radically reduce the rate of accumulation in greenhouse gases. Policies to encourage adoption of these technologies are already being considered by the Congress and other government agencies to serve other important societal objectives. Some relevant decisions likely to be faced in the current Congress include repeal of the Fuel Use Act and other disincentives to high-efficiency gas turbines; enactment of the National Appliance Efficiency legislation; and modest budgetary support for development of high-efficiency electric motors and vehicles, alternative transportation fuels, and

photovoltaic cells.

Our ability to anticipate emerging environmental needs also ought to be a central element of efforts to improve our economic competitiveness. Investments in alternatives which meet these needs will help rather than hinder our long-run economic growth.

One Atmosphere: Three Linked Problems

The linkages between greenhouse warming, stratospheric ozone depletion and air pollutants are pervasive. Near-term decisions concerning air pollution and ozone depletion policies are therefore an important starting point for raising the longer-term considerations associated with global climate change. Long-range environmental planning may be a prerequisite for the larger governmental role that may ultimately be necessary.

The greenhouse, ozone depletion, and air pollution problems are tied together by the same chemical species, by the same human activities which generate them and by the effects of one phenomenon on the timing and severity of the others. The leading parts in each are played by the same actors, though sometimes in different roles: carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), carbon monoxide (CO), ozone (O_3), nitrogen oxides (NO_x), sulfur oxides, (SO_x), the hydroxyl radical (OH), and the chlorofluorocarbons. As a consequence, the effects of policies made to address any one of these linked atmospheric problems can have critical impacts on the evolution of the other two problems.

For example, in the troposphere, CO_2 is the largest contributor to global warming and climate change. However, CO_2

molecules, when they are carried into the stratosphere, cause a local cooling effect and slow the rate of many reactions which would otherwise lead to ozone depletion. Methane's role is even more complex. In the troposphere, methane reacts chemically with other atmospheric pollutants to increase ozone concentration at low altitudes. Once it reaches the stratosphere, some methane molecules combine with free chlorine atoms, reducing the amount of ozone depletion. Others react to form CO_2 and water vapor, amplifying the greenhouse effect. Sulfur oxides, in the presence of high concentrations of tropospheric ozone, hydroxyl radicals, and other oxidants, are converted to sulfates, leading to acid deposition.

Ozone, like methane, plays a very complex role in the atmosphere. Its impact varies strongly with altitude. In the upper atmosphere, it plays an important beneficial role by absorbing ultraviolet radiation, which, if allowed to reach the Earth's surface, would cause damage to plants, animals, and humans. At high concentrations close to ground level, ozone is an important pollutant with strong negative effects on plant growth and on human health.

The same energy-related activities generate most of the pollutants which are central to all three of these problems. For example, a family refrigerator may inadvertently contribute to all three problems. If the electricity to run the refrigerator is generated from coal, as is the case in many parts of the U.S. today, its use results in emissions of CO_2, N_2O, NO_x, and SO_x.

When the device wears out and is discarded, its disposal for scrap is likely to result in emissions of the CFCs embodied in its walls and cooling loop. The emissions of CO_2, N_2O, and CFCs will contribute to global warming and ozone modification while the SO_x and NO_x are likely to increase the risk of acid deposition.

When the same family drives its air-conditioned car to the store for groceries, the combustion of gasoline produces emissions of CO_2, NO_x, and hydrocarbons (which increase the concentration of tropospheric ozone). Leaky hoses and fittings in the air conditioner result in a slow flow of CFCs to the atmosphere. The resulting increases in atmospheric concentrations of CO_2, CFCs, and tropospheric ozone add to the greenhouse effect. The buildup of CFCs in the stratosphere increases the risk of ozone depletion at high altitudes while the increased concentrations of NO_x and tropospheric ozone raise the probability of negative effects on plants and human health and damages from acid deposition.

These examples indicate the complexity of interactions, both chemical and economic, that link these three problems. The natural tendency to use different names for the phenomena creates an illusion that these are distinct sets of changes. They are not. Acid deposition is just one of the results of a far more complex mix of air pollutants including ozone and nitrogen oxides that interact to affect plant, animal, and human life. The greenhouse warming and ozone depletion are so closely tied they

must be treated as one phenomena for policy purposes. Above all, as costs and benefits of controlling any one of these pollutants are weighed by this Committee, the effects on all three problems must be considered.

The Timing of Global Warming

Whether or not policies today should be shaped by the consideration of future global warming depends on the timing and severity of expected impacts and the extent to which available choices can influence the ultimate outcome. Is the greenhouse effect a problem for our great-grandchildren or will we see its impacts in our own lives? Given the scientific uncertainties, is it too soon to act? Can anything done today make a significant difference? If we wait to make policy choices until the science is certain, will we pay any greater price?

Answering these questions begins with an understanding of the current status of the atmosphere. Although policy decisions must necessarily be national in character, these questions must first be evaluated at a global level. Due to the historic pattern of emissions since the Industrial Revolution, the atmosphere today is far from thermal and chemical equilibrium. The pollutants which cause the greenhouse effect have very long lifetimes in the atmosphere; emissions from industrial activities at the turn of the century continue to affect the atmosphere today. Because of various lags and feedbacks in the biological and physical systems governing the planet, some of the effects

have still not been felt.

The correct measure of the greenhouse effect is not how much warming has been observed to date but rather what warming the atmosphere is committed to, since the time of emission is the point of irreversible commitment. Emissions from 1860 to 1980 may have already committed the planet to an increase of 0.5-1.5° C above the average global surface temperatures in the middle of the last century, allowing for uncertainties due to various feedback effects.

Research by WRI's Dr. Irving Mintzer and our colleagues at the Institute has led to the development of a modelling tool that can illuminate the effects of future emissions on the timing of global warming. Individual components of the model can be separately manipulated to simulate the effects of hypothetical policy and economic changes on future emissions of the principal greenhouse gases. Mintzer's "base case" scenario reflects conventional wisdom regarding population, economic activity and energy growth from 1980 to 2075. No specific policies are introduced to limit the rate of greenhouse gas emissions. No major effort is made to slow the rate of tropical deforestation or its contribution to CO_2, N_2O, CH_4, or CO emissions. No special attention is directed to improving the efficiency of energy use. Environmental concerns do not shape energy policy. Substantially lower than historic rates of growth in CFC emissions are projected for the future although no specific policy interventions are incorporated to assure these reductions.

The model predicts a commitment to average global warming of 0.9 - 2.6° C above pre-industrial levels by the year 2000. A warming of only 2° C -- well within this range (and what some analysts believe the world is committed to already) -- would put the global temperature far beyond that experienced in recorded human history. Simply a continuation of current trends would quite likely commit the atmosphere to this potentially radical change in climate by the turn of the century.

Looking out to 2030, Mintzer's model projects a commitment to average global warming of 1.6 - 4.7° C (about 3-8° F), the equivalent of doubling the pre-industrial level of CO_2. This new and very different climate regime is rapidly approaching. Allowing current trends to continue would commit the world to such a warming at a point no farther into the future than World War II is distant in the past. Forty-five years is a relatively short time to make large-scale changes in patterns of industrial activity; studies have shown that new energy supply technologies (which might slow this change) rarely capture as much as half the global market in as little as fifty years.

Mintzer has also used his model to investigate scenarios that reflect major changes from current trends. He has analyzed a "high emissions" scenario where increased use of coal and synfuels is encouraged, deforestation increases, and energy prices continue to ignore the environmental costs of energy use. CFC use is projected to grow with rising incomes in other regions at close to the high historic rates observed in the development

of the U.S. market. To provide a counterpoint in the analysis, a "slow buildup" scenario was constructed to investigate the effect of strong global efforts to introduce solar energy, improve energy efficiency, discourage increased use of solid fuels, and limit deforestation. CFC production and use is controlled in this scenario by international agreements to protect the ozone layer. In the high emissions case, the rate of emissions growth is accelerated and the date of commitment to the equivalent of doubled CO_2 advances from 2030 to 2015. By contrast, in the slow buildup case, this commitment is delayed beyond 2075. Thus, the model results suggest that the commitment to a global warming equivalent to doubling the pre-industrial level of CO_2 can be changed by as much as 60 years as a result of choices before us today and the very near future.

What is the cost of delaying action while we seek better scientific understanding? The appeal for greater certainty is powerful, for there are important gaps in our ability to estimate the risks. Many scientists suggest that significant improvements in our understanding of the role of the oceans and of clouds in the climate system will take twenty years to achieve. Allowing an additional decade to achieve political consensus concerning appropriate responses, 2015 might be the earliest point at which a more confident choice could be implemented. According to Mintzer's model, proceeding with current trends (the "base case" scenario) until 2015 would commit the planet to 0.25 - 0.8° C more warming than if the policy changes represented by the slow

buildup scenario are implemented today. Thus, if no action is taken for 30 years, the planet's climate system would be committed to a warming equivalent to about half again as much as has occurred since the Industrial Revolution -- a large potential cost of delay.

Is A Slow Buildup Scenario Feasible?

The importance of the rate of accumulation in greenhouse gases is uncontestable. Nevertheless, some argue that there is little or nothing that can be done to influence our fate, that governments either have no real ability to make a difference or that the necessary policies are politically unimaginable. They propose that all our policy resources go toward strategies for adapting to the inevitable.

In our view this "adaptionist" approach is not only wrong but potentially dangerous. It is wrong because there are many feasible, economically attractive opportunities for reducing greenhouse gas emissions, as I describe below. It is dangerous because it risks delaying action until the consequences are catastrophic and the options far more limited. The longer society waits, the more rapid, expensive, and disruptive the slowdown may have to be, especially if in the interim commitments are made that increase global reliance on coal, tar sands, oil shales and other carbon-rich fuels.

The dangers associated with an adaptionist approach are

easily demonstrated. The range of impacts associated with even relatively modest climate change is likely to be enormous. The human costs that would accompany, for example, flooded coast lines or shifts of hundreds of miles in areas suitable for farming is too often ignored. The 1930s dust bowl "adjustment" no one would willingly repeat. The risks to plants and wildlife are also usually not recognized; populations within parks and wildlife preserves would be lost, and biologically vital coastal communities would be severely at risk. Some unpredictable, unpleasant surprise is almost inevitable. Finally, even adaptionists must at some stage become preventionists, since at some point the global warming must be stopped. No one believes society as we know it can adapt to, say, a 15° C global average warming. The sooner we begin to slow the warming trend, the easier and less disruptive the process is likely to be on all counts.

What can be done to retard global warming? There are four complementary strategies: reducing emissions of CFCs through substitution and recycling; slowing tropical deforestation to reduce the biotic contribution of CO_2; increasing the efficiency of energy use to reduce total fossil fuel combustion; and substituting less CO_2-rich fuels -- notably natural gas, and perhaps, in the long term, nuclear power, for coal and oil. In some cases specific policy measures are readily available and can be implemented today, in others, additional research and development will be required. We must also promote similar

strategies in other countries, particularly the developing countries where much of the global increase in greenhouse gas emissions is most likely to occur.

Limiting CFC Emissions

In recent years, emissions of chlorofluorocarbons have grown more rapidly than emissions of other greenhouse gases. Fortunately they are arguably the most easily controlled. Substantial progress has already been made toward the completion of an international agreement to protect the ozone layer that will limit CFC emissions, with the motivation being almost entirely the need to protect the ozone layer. The U.S. government is to be commended for proposing that countries cap their CFC emissions at current levels and begin a long-term phase out of these chemicals. When the dual role of CFC emissions as ozone destroyers and potent greenhouse gases becomes widely recognized, it should be possible to reach prompt international agreement for a strategy at least as strict as the current U.S. proposal -- and perhaps considerably tighter. A recently released WRI report by Alan Miller and Irving Mintzer, "The Sky Is the Limit: Strategies for Protecting the Ozone Layer," documents opportunities for reducing CFC emissions by one-third in the near term and recommends a tax of $5 per pound to promote long-term development of substitutes. A copy of this report has been given to the Committee.

Curtailing Tropical Deforestation

The importance of curtailing tropical deforestation as a response to the greenhouse problem is also receiving increasing international attention. The biotic contribution of CO_2 is uncertain but may be as much as 40 percent. A recent report prepared by an international task force convened by the World Bank, the United Nations Development Programme, and the World Resources Institute, Tropical Forests: A Call for Action, sets out a detailed agenda for sound management of forest resources. While the task is daunting, the initial response to this report from international development assistance institutions and governments and community leaders in the tropical nations affected has been highly encouraging.

Increasing the Efficiency of Energy Use

Unquestionably, the most significant reductions in CO_2 emissions can be achieved through increasing the efficiency of energy use in both developed and developing countries. In every economic sector, currently available technologies are far more efficient than those now in use, and technologies now under development are expected to be even better. The U.S. experience post-1973, in which energy use actually declined despite a substantial increase in GNP through 1985, can be extended and improved. Greater use of currently and soon to be available technologies in the centrally planned economies and developing countries would further increase the positive impact on global

CO_2 emissions.

One of the most important opportunities for reducing electricity consumption is through the application of new materials and control systems to electric motors.[1] Nearly two-thirds of electricity used in the U.S. goes to electric motors. The use of variable speed controllers, high performance permanent magnet materials, and other improvements offers the prospect of energy savings of 30 percent or more. Some additional research and commercial development is necessary. Much is being done in Japan, less in the U.S.

The opportunities for reducing the electricity used for lighting are also substantial.[2] About a fourth of U.S. electricity consumption is for lighting. High frequency ballasts, isotopic enhancement, advanced control circuits, and other technologies are being incorporated in commercial products to reduce energy by 50 percent or more. These technologies have a higher first cost but pay for themselves in greatly reduced operating costs.

Building codes administered at a state or local level have considerable influence on the energy consumption of buildings, including the technology used for lighting. A federal program addressed to this area was repealed shortly after President

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[1]Sam Baldwin, "New Opportunities in Electric Motor Technology," IEEE Technology and Society Magazine, March 1986, pp. 11-18.

[2]Samuel Berman, "Energy and Lighting," in D. Hafemeister et al, Energy Sources: Conservation and Renewables.

Reagan took office, but the influence of consensus standards produced under the auspices of the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) remains enormous, and this process may soon produce tougher standards for lighting, heating, and cooling buildings. If this process is unsuccessful, federal legislation may be necessary.

Appliances offer yet another illustration of opportunities for electricity conservation.[3] Replacing existing refrigerators and water heaters with the most efficient models available would reduce demand by the equivalent of 27 large power plants (27,000 megawatts), and considerably more efficient designs than those presently available have been developed.

Last year, Congress legislated minimum efficiency standards for appliances, a bill which was vetoed by the President after Congress adjourned. Identical legislation has been reintroduced with the support of several members of this Committee and merits quick passage. A number of states already have standards and others will follow suit if there is no federal program. Numerous electric utilities have implemented rebate programs that provide a financial incentive for purchases of more efficient appliances. Several utility commissions have supported information programs that tell consumers which products are most efficient and help in analyzing their economic advantage.

The greatest opportunities for reducing oil consumption lie

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[3]Howard Geller, "Energy Efficient Residential Appliances," IEEE Technology and Society Magazine, March 1986, pp. 4-10.

in improving automobile efficiency. While substantial improvements have been achieved in the last decade, here, too, new technologies offer remarkable promise.[4] Prototype vehicles (produced by European and Japanese companies) incorporate light-weight plastics, continuously variable transmissions, and other new technologies to achieve in excess of 70 mpg consistent with roomy interiors, safety, and high performance. A Toyota prototype 4-5 passenger car has a fuel economy of 98 mpg.

Proposals to further tighten automobile efficiency standards in the U.S. have not received serious consideration for several years. In fact, the Administration has sought to weaken existing standards whenever possible, and has even supported repeal. The recent resurgence of concern about the rapid rise in oil imports and prospects for a return to dependence on OPEC in five to ten years should, however, bring renewed interest in achieving further efficiency in the transportation sector.

Each of these opportunities taken individually is impressive, but the aggregate effects obtainable globally from a consistent application of energy efficiency strategies are remarkable. In a global analysis supported by the World Resources Institute, energy experts from four countries applied an end-use approach to global energy demand to suggest the magnitude of the opportunities for reducing the world's energy

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[4]Jose Goldemberg, Thomas Johanson, Amulya Reddy, and Robert Williams, Energy for a Sustainable World (Washington, D.C.: WRI, 1987).

needs.[5] By applying the most efficient technologies available to produce different services, they estimated the minimum amount of energy necessary consistent with expected population growth and optimistic projections of increased economic activity. Their results are enormously encouraging -- a total level of global energy use in 2020 not much higher than at present. This contrasts with a doubling or tripling of energy demand in conventional analyses. (Figure 1)

The importance of this difference for curtailing the emission of greenhouse gases and delaying global warming is difficult to overstate. Of course, this assessment is not a prediction of what will happen but rather a description of what is technically and economically possible.[6] The improved performance and economic attractiveness of most of these recently developed technologies is such that they will be adopted eventually. However, from the perspective of the greenhouse problem, the rate at which new technologies are adopted is critical and becomes a policy issue of considerable importance.

Ironically, the loss of governmental support for the further development of energy efficiency technologies may lead us to import more efficient products from other countries. Almost all

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[5] Ibid.

[6] While this report is unique in the detail of its analysis, it is not alone in identifying efficiency improvements as a very promising strategy for reducing CO_2 emissions. A report prepared for the Department of Energy last year by Steinberg, et al. and a 1983 study by Rose, Miller and Agnew of the MIT Energy Laboratory also reached consistent results using very different methods.

commercial development of permanent magnetic materials -- an important component of high-efficiency motors -- has occurred in Japan. Japan provides $30 million a year in matching support for development of photovoltaic devices (PV's) -- $10 million more than the budget proposed by the Administration -- and last year exceeded U.S. production by a considerable margin. Similarly, much more commercial development of high-efficiency vehicles is taking place in Japan and Europe than in the U.S. As such products emerge as part of the answer to a new energy crisis and the related problem of global climate change, it is likely to be at the cost of a further erosion in the economic competitiveness of the United States, unless our policies are altered.

Fuel Substitution

Increased reliance on natural gas could reduce emissions of CO_2 because it's carbon content per kilocalorie is only about 50 percent of coal and 70 percent of oil. Major technological developments have occurred in gas turbine design due to related research on aircraft engines and materials which offer the prospect of low capital cost, short installation time, and high efficiency.[7] They can also be operated efficiently in relatively small sizes, allowing additions to capacity as needed -- greatly reducing planning uncertainties that have been the bane of the utility industry.

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[7]Robert Williams and Eric Larson, "Steam-Injected Gas Turbines and Electric Utility Planning," IEEE Technology and Society Magazine, March 1986, pp. 29-38.

The Powerplant and Industrial Fuel Use Act discouraged utilities from burning natural gas in efficient new powerplants while allowing continued use in inefficient old plants. Repeal of this statute is possible this Congress. Utilities blame some state regulatory policies that preclude recovery of extra costs associated with trying new technologies such as high efficiency gas turbines for discouraging adoption of promising technologies. As a result, markets have appeared first overseas and U.S. manufacturers have been at a competitive disadvantage.

The long-term availability of natural gas is uncertain and highly controversial. However, with these highly efficient turbines, even current utility consumption of gas would support an increase in power generation equivalent to the output of 26 large coal or nuclear plants.

Rapid recent progress in the development of high efficiency and low cost photovoltaics also offer the renewed promise of reduced greenhouse gas emissions. Developmental research funded by the Electric Power Research Institute has led to recent successes in the area of concentrating collectors that could help photovoltaics make a significantly larger contribution in utility central-station applications. Advances made by Japanese companies in the area of thin-film, amorphous semiconductors are rapidly reducing the cost of photovoltaic devices. Unfortunately, this Administration has chosen to reduce the level of federal support for R and D on photovoltaic systems by more than a factor of four since 1981. As a result, the substantial

technological lead enjoyed by U.S. semiconductor firms in the 1970s will soon pass to our overseas rivals, especially the Japanese. Increased federal support for photovoltaic research could quickly turn this situation around and increase the probability that photovoltaics could, in the near term, displace significant amounts of carbon-based fuels for electricity production.

Another possible opportunity for fuel substitution to reduce greenhouse gas emissions is the transportation sector. Compressed natural gas, methanol and ethanol can be used in automobiles with relatively minor modifications.[8] California and New York have programs to test CNG and methanol on state vehicles, providing valuable experience. A large percentage of Brazilian vehicles now operates on ethanol produced from sugarcane. Although the energy density of these fuels is less than that of gasoline refined from crude oil, they have other properties that allow increased efficiency and performance. An important goal for further research is to avoid new environmental impacts arising from large-scale deployment of these systems.

The Importance of Other Countries

Another element of the policy puzzle is the influence the U.S. has on energy policy in other countries. U.S. energy use is

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[8]Thomas Bull, "Liquid and Gaseous Fuels form Biomass," in Energy Sources: Conservation and Renewables, D. Hafemeister, H. Kelly, and B. Levi, eds. (New York: American Institute of Physics, 1985).

about one-quarter of global consumption -- significant, but not in itself controlling. However, the policies we adopt can and do influence the decisions of other countries; what we do affects much more than one third of the problem. For example, U.S. leadership on reducing CFC emissions has been a major factor in the evolution of support for an international agreement.

The U.S. has arguably even greater leverage in the developing countries, where much of the potential increase in fossil fuel combustion and tropical deforestation is predicted to occur. Through the energy programs of the Agency for International Development and our influence on the lending policies of the multilateral development banks, we could encourage investments in energy efficiency instead of new central power stations and promote a global understanding of the seriousness of the energy-climate change problem, were we so inclined. Investments in energy efficiency will stimulate local economic growth and help to ease the debt crisis because these investments typically require significantly smaller amounts of foreign exchange than do the alternative investments in increased energy supply that they replace.

Policies to Buy Time

Measures such as those described above could substantially reduce the risks of climate change and buy time for a more detailed understanding of the problem and for adaptation to changes that cannot be avoided. What is missing most is detailed

analysis of the policies necessary to implement these measures and achieve a "slow buildup" scenario. Efforts in this direction have been initiated at EPA at the request of this Committee, a step we strongly support. However, the Department of Energy unfortunately still maintains that such analysis should be postponed for at least a decade pending further research. WRI plans to conduct further analysis of specific policy options using the simulation model described above. These studies will serve to elaborate and refine our estimates of the effects of policies implemented by different coalitions of countries on the timing and severity of future global warming.

Thus, policy proposals for responding to the greenhouse problem are as yet necessarily tentative. Nevertheless, it is apparent that much can be done consistent with other short-term environmental and economic objectives. Reductions in emissions of CFCs appear likely and efforts to slow tropical deforestation have been initiated. There are also near-term opportunities for promoting energy efficiency and fuel substitution, despite the diminished concern about energy in recent years.

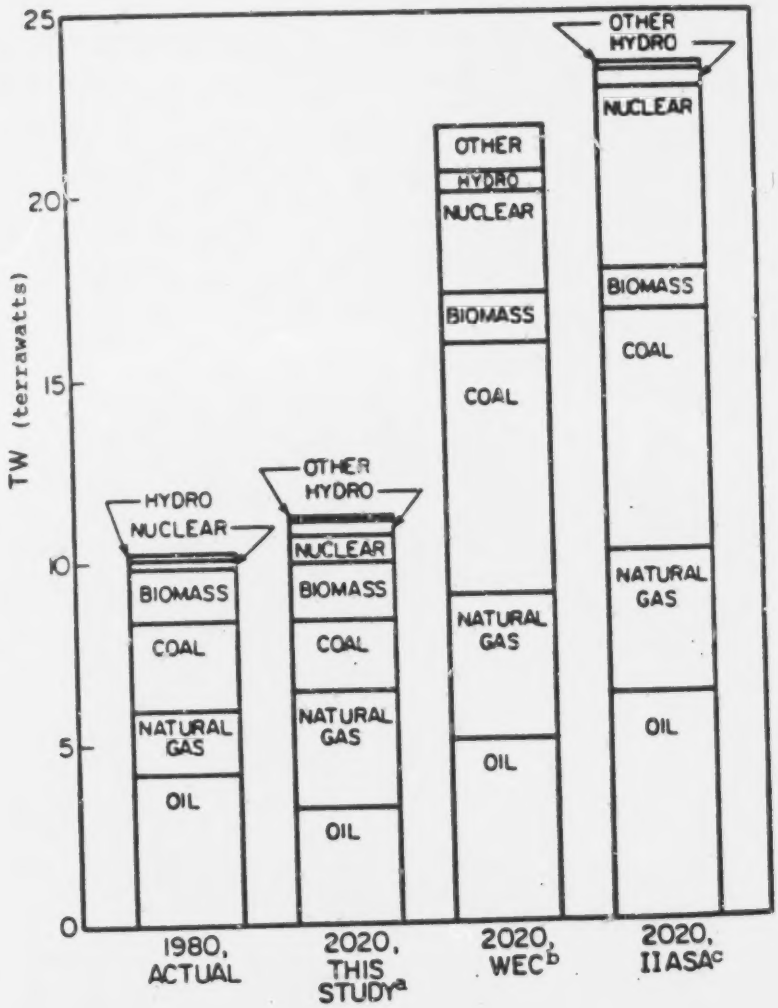
The Clock Is Ticking

The greenhouse clock is ticking. A substantial global warming is already "in the bank". Since greenhouse gas emissions are accelerating, additional warming will be committed to much faster than in the past. A reasonable estimate of the current path we are on suggests a commitment to future warming of 0.9-

2.6° C above pre-industrial levels by 2000 and 1.6 - 4.7° C by 2030. On the other hand, the planet is not bound to a warming of this magnitude in such a short period. Politically optimistic but economically attractive policy changes undertaken now could significantly slow the anticipated warming. Waiting for greater scientific certainty would probably result in an additional warming "in the bank" of 0.25 - 0.8° C. Such an additional commitment would mean that future policies would have to be much more draconian to achieve the same level of control.

Achieving a new domestic consensus on energy policy will be a major challenge. Building the necessary international consensus on policy responses to global warming and ozone depletion will be even more difficult. Fortunately there are a number of significant steps that can be taken today that will make substantial progress toward this goal. By pressing the analysis and adoption of feasible policies, this Committee can play a pivotal role in meeting this challenge.

Figure 1. A comparison of the total energy use and fuel mix for three energy scenarios in 2020



a. J. Goldemberg, T. Johansson, A. Reddy, R. Williams, "An End-Use Oriented Global Energy Strategy," Annual Review of Energy Vol. 10, p.. 613-88 (1985)

b. World Energy Conference 1983 forecast

c. International Institute for Applied Systems Analysis, Energy in a Finite World -- A Global Systems Analysis (Cambridge, Mass: Ballinger, 1981).

ALLIANCE FOR RESPONSIBLE CFC POLICY
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STATEMENT

OF

RICHARD BARNETT
CHAIRMAN
ALLIANCE FOR RESPONSIBLE CFC POLICY

TO

SENATE ENVIRONMENT & PUBLIC WORKS COMMITTEE

JANUARY 28, 1987

Mr. Chairman, Committee Members, the Alliance for Responsible CFC Policy appreciates this opportunity to present its views concerning the ongoing international negotiations on a protocol for protection of the ozone layer.

The CFC Alliance is a coalition of more than 500 U.S. business users and producers of chlorofluorocarbon (CFC) chemicals. CFCs, which have been examined for their role in contributing to the potentially harmful depletion of the stratospheric ozone layer, are used in several essential industries such as air conditioning and refrigeration, electronics, automobile, food processing, foam and plastics, and several others. They are used because of their unique combination of highly desirable properties and characteristics. They are non-toxic, non-flammable, non-carcinogenic, non-corrosive, and in most of their applications, very energy efficient.

The Alliance has been organized since 1980 to promote the development of responsible policies concerning both the use of CFCs and the potential for any further regulation of their use. Since that time, we have urged that consideration and examination of these issues should be pursued at the international level, that policy decisions be based on the most current and best scientific information available, and that we not force the premature substitution of CFCs without balancing the environmental need as well as the health and safety characteristics of the substitute chemicals.

We believe we have played a positive and important role in the policy discussions during the intervening years, including our support for and promotion of the 1985 Vienna Convention for Protection of the Ozone Layer, which was ratified by the Senate in 1986 with our support.

In 1986, as part of our continuing assessment of scientific understanding and our views of the responsible policies that flow therefrom, the Alliance announced a revised policy statement, a copy of which is attached.

The key elements of our policy call for:

(1) The negotiation of an international agreement under the auspices of the United Nations Environment Programme (UNEP) on global production capacity for the fully-halogenated CFCs;

(2) The development of voluntary CFC conservation programs by user industries;

(3) The continued development of scientific understanding of the ozone depletion theory;

(4) The research and development by producers and users of alternative CFCs, products and processes to reduce reliance, if necessary, upon the fully-halogenated substances.

Our policy is sequentially logical, grounded in our current assessment of the scientific understanding, and important to the successful resolutions of the issues we are discussing, both from the standpoint of environmental protection and from the perspective of concern for maintaining U.S. jobs and healthy U.S. industries.

Successful completion of the negotiations currently underway at UNEP is absolutely essential for the effective scientific understanding and policy resolution of the ozone depletion issue. The U.S. has shouldered much of the research burden to-date in developing better understanding of the earth's climate and atmosphere. Greater world cooperation and financial support would serve us better in the continued effort to develop scientific consensus.

Furthermore, the U.S. only produces and uses approximately one-third of the world's chlorofluorocarbon supply. If CFC emission controls or reductions are necessary, then unilateral regulation of U.S. industry would provide only limited environmental benefit, remove us from the international bargaining table, and potentially damage U.S. industries in the increasingly competitive world market.

In the name of international environmental leadership, the U.S. banned the use of CFCs as aerosol propellants in 1978. The resulting world reaction is that only a handful of countries followed us, and today, aerosol propellants remain the single largest use of CFCs outside the United States. We are the only producing nation to actually dismantle production capacity.

The Alliance's policy was adopted in the hope that it would enhance the environment at the UNEP meetings and foster a greater cooperative spirit among the UNEP participants. We believe, on the basis of the negotiating session last December, that our policy has accomplished this objective. We intend to continue our participation in the UNEP process and continue to urge our industry brethren around the world to cooperate with their governments as we strive for a fair but effective protocol. We are adamant about our desire for an international agreement as the logical next step in the policy development process. We are not naive as to the difficulties or complexities that remain in our path. But if the Congress and the Executive branch are as committed to this process as are we, then it is a sensible and achievable objective.

This does not mean, however, that our industries in the U.S. are doing nothing to keep the proper perspective on this issue. In November, the Alliance hosted a meeting of more than 20 trade associations representing thousands of businesses, large and small, that use or produce CFCs. Following a thorough discussion of the scientific information and the domestic and international policy issues, we asked for their support in an effort to gather answers to these critical questions: Where do we use CFCs, Where do we lose CFCs through emissions, and What options do we have to reduce those losses? These are

difficult questions, but questions we feel must be answered.

I am pleased to tell you that we received no dissent from the organizations represented to participating in this effort. Furthermore we have assisted in the establishment of task forces in all of the major use areas to begin the work to gather this information. Although it is too early to have concrete results, we are heartened by the overwhelming expressions of support by these industries for our policy and by their willingness to participate in this process.

Our work in this area begins from the premise that if CFCs are a problem, they are a problem only if they are emitted. Therefore, the logical first question we must answer is can we learn to conserve and use CFCs more efficiently, thereby reducing emissions. If the answer to this question is yes then, in our view, these cost-effective measures can and should be taken. Whether these measures should be mandatory relates to the issue of scientific necessity rather than the mere possibility of accomplishing the reduction.

Ultimately, any steps taken beyond the agreement reached at the international level should be based on what the science tells us is <u>necessary</u>. The research and development work that is necessary to provide the conservation technologies and/or new CFC formulations will be driven by market forces, including the international agreement, attention by policy makers, media, and industry, to environmental concerns, and

and competitive pressures for technological advancement.

These market forces are already coming into play. It is unnecessary, at this time, for further intervention into the process over what is already occurring. The industries and companies within industries cover a varied range of options for acting on this issue. Some steps are easy, some steps are not, many have not yet been discovered. But we are asking the right questions.

Finally, it is unfortunate that because of our laws and legal system, EPA is required to propose some regulatory decision in May and publish a final rule at the end of this year. We remain concerned that whatever steps may be considered or proposed by the agency might have the unfortunate effect of hindering the international negotiations process by providing other nations with an incentive not to negotiate. Neither U.S. citizens nor the world will be best served by the U.S. government indicating it is going to act unilaterally. Many of our world competitors are perfectly willing to let us shoulder the burden if we intend to take it upon ourselves to do so. The timeframe for EPA's decision should be extended so it does not interfere with the international process.

In summation, the CFC Alliance believes it has charted a course to allow us to manage this issue in a fair, effective, and environmentally sensible manner. The scientific consensus today suggests no imminent threat to human health and the environment from current CFC production or use. We have time

to reach the international agreement that is critical to the continuing development of scientific and policy consensus. We have time to develop voluntary conservation programs and to do the research and development for longer-term technical solutions, if they are required.

But the United States cannot solve this environmental issue on its own, nor should it, nor should we pursue solutions that are not required scientifically or sensible from an environmental standpoint.

In our view, a real opportunity exists to succeed if we keep focused on our goal. We have a reasonable prospect for reaching an effective international agreement, we have an active assessment program at EPA, albeit short-fused, and a cooperative industry calling for progressive action.

I would like to commend the Chairman for calling these hearings and helping to maintain our focus on the global effort. We hope that the Congress will be patient and supportive of the international process. We look forward to being an active participant.

Thank you for the opportunity to appear before you today. I will be happy to respond to any questions that you may have.

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Embargoed For Release Until:
9:00 a.m., September 16, 1986

POLICY STATEMENT

Chlorofluorocarbons (CFCs) are widely used by industry and the general public and contribute significantly to the quality of life in the United States and around the world because of their unique and beneficial combination of functional properties and excellent safety characteristics. The Alliance for Responsible CFC Policy was organized in 1980 to ensure that government policies regarding the further regulation of CFCs are responsible and that any such policies are based on sound scientific facts. It was a further objective of the Alliance to encourage that efforts be pursued on an international basis to resolve the scientific uncertainties pertaining to the ozone depletion theory, the role of CFCs, and the need, if any, for global action to protect the ozone layer. Since 1980, significant scientific research has been conducted concerning the ozone depletion theory, the greenhouse effect, and the role of CFCs. Significant scientific uncertainties remain, however, and the research needs have grown much more complex. Based on the theory, current scientific understanding, and reasonable assumptions about future emissions of substances that may modify the ozone layer, no significant modification of the ozone layer is expected during the next few decades, therefore, there is no imminent threat to human health and the environment from current CFC use or emission. On this basis, the Alliance believes that the following position statement provides an outline for responsible U.S. policy with regard to CFCs compatible with current scientific understanding and consistent with the original goals of the Alliance:

* Recognizing the global nature of the ozone depletion theory, the Alliance supports international resolution of the issue. Additional unilateral regulation of CFCs by the United States would provide little, if any, environmental protection, injure U.S. industry to the benefit of international competition, and may undermine efforts to obtain an international resolution.

* Additional scientific research is essential. The Alliance supports the atmospheric research recommendations contained in the January, 1986 NASA/World Meteorological Organization Science Assessment.

* Voluntary conservation in CFC end uses should be continued and expanded where economically and technologically practical.

* Regulation of specific uses of CFCs is ineffective and discriminatory.

* Responsible policy dictates, given the scientific uncertainties, that the U.S. government work in cooperation with the world community under the auspices of the United Nations Environment Programme to consider establishing a reasonable global limit on the future rate of growth of fully halogenated CFC production capacity.

* Development of alternative products and processes should be encouraged to utilize suitable alternatives to fully halogenated CFCs.

* Research should be continued and expanded to develop substitutes for fully halogenated CFCs.

TESTIMONY OF DAVID D. DONIGER
SENIOR ATTORNEY, NATURAL RESOURCES DEFENSE COUNCIL
ON PROTECTION OF THE OZONE LAYER AND GLOBAL CLIMATE
FROM CHLOROFLUOROCARBONS, HALONS, AND RELATED COMPOUNDS

BEFORE THE
SUBCOMMITTEE ON ENVIRONMENTAL POLLUTION AND THE
SUBCOMMITTEE ON HAZARDOUS WASTE AND TOXIC SUBSTANCES OF THE
SENATE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
JANUARY 28, 1987

Mr. Chairman and members of the committee, thank you for the opportunity to testify at this oversight hearing on international and domestic efforts to protect the stratospheric ozone layer and the global climate from chlorofluorocarbons (CFCs), halons, and related man-made gases. These efforts are now at a crossroads. They could turn out very well or very poorly depending on decisions made by the Environmental Protection Agency and the Department of State in the coming weeks and months. The close scrutiny of the Congress is especially timely and necessary.

These chemicals share two destructive capabilities: First, with lifetimes in the lower atmosphere as long as a century or more, they can reach the stratosphere and deplete the ozone layer, increasing the amount of ultraviolet (UV-B) radiation that penetrates to the earth's surface. Second, while in the lower atmosphere these chemicals absorb infrared solar radiation, converting it to heat that contributes to the global warming.

Ozone depletion from CFCs was first forecast more than a decade ago. The early hypothesis survived the most severe scrutiny and is now the consensus scientific view. Increases in UV-B radiation due to ozone depletion will cause serious, potentially disastrous, damage to public health and the

environment in the U.S. and throughout the world. According to the EPA risk assessment issued in draft in November 1986, as many as 40 million extra skin cancer cases (800,000 of them fatal) and 12 million extra cataracts will occur just in the U.S. between now and 2075 if CFC emissions are allowed to continue growing at recent historical rates.

These estimates touch on only the most easily quantified health consequences. Increased UV-B radiation is also believed to suppress immunological systems, possibly leading to increases in rates of hepatitis, herpes, and other serious diseases. More UV-B will also cause higher levels of ground-level ozone -- "smog" -- in urban atmospheres. Approximately one person in five is especially sensitive to ozone smog levels already common in urban areas. Increased UV-B will also cause serious environmental harms: including reductions in crop yields, widespread damage to forests and other vegetation, and possible disruption of critical aquatic food chains. There may also be unpredictable climate changes due to the latitudinal and vertical redistribution and overall loss of ozone.

Reality, in fact, may be substantially worse than theory. An enormous hole in the ozone layer is opening over Antarctica each October, with ozone losses as great as 40 percent. Scientists investigating the Antarctic ozone hole believe chemical processes are likely to be responsible; CFCs are a prime suspect. In addition, NASA satellite data now under careful review indicates that large global ozone reductions may have

occurred over the past several years. The measured ozone losses exceed model projections by as much as eight times. If these findings are confirmed and linked to CFCs, then we will have an emergency of global proportions on our hands.

In the lower atmosphere, CFCs, halons, and related compounds absorb infrared radiation reflected from the earth's surface, contributing to the "greenhouse effect." While carbon dioxide is the single most important global warming gas, on a molecule-for-molecule basis CFCs absorb 10,000 times more infrared radiation than CO_2. CFCs and related gases account for about one-sixth of the current stock of greenhouse gases in the atmosphere, and they are growing more rapidly than the others. Climate change exacerbated by CFCs, halons, and related compounds will also have severe effects on health. Urban death rates will rise as the number and severity of summertime heat waves increase. Hurricanes, other storms, and flooding will likely occur more often, causing large losses of life and property. Changes in the distribution of rainfall will have dramatic effects on crop yields, drying up whole agricultural regions and destabilizing world food production. Sea level rise will cause enormous economic damage and human disruption in coastal areas. Controlling greenhouse gases must become a national and international priority. Curbing CFCs, halons, and related gases is an important first step that must be taken.

The most striking difference between these pollutants and other types of pollution is that CFCs and related gases

accumulate in the atmosphere: for practical purposes nearly all of the CFCs emitted in the past are still in the atmosphere. The accumulation of these gases means that the problem is continually worsening and regulatory delay will be extremely costly.

As you know, the State Department and EPA are now in negotiations with other nations in an attempt to reach an international agreement this year for curbing emissions of CFCs and related substances. EPA is also on a schedule to make an independent decision on curbing domestic emissions of these compounds; a proposed decision is due on May 1 of this year and, after opportunity for public comment, a final decision is due on November 1. The schedule is contained in a court order entered to settle a citizen suit brought by the Natural Resources Defense Council (NRDC) to obtain further control on CFCs.

Over the past year NRDC, along with the Environmental Defense Fund (EDF) and others, has met with EPA and State Department officials (including Administrator Thomas and Ambassador Benedick). We have also met several times with the industry trade group, the Alliance for Responsible CFC Policy, to explore areas of commonality. We attended the Geneva negotiating session in December 1986 as observers and met there with representatives of other governments. We are closely cooperating with European environmental groups in favor of controlling these substances. We will be in Vienna at the next session in February.

On each occasion, we have emphasized (1) that no level of stratospheric ozone depletion or global warming caused by CFCs and related compounds can be considered acceptable, (2) that emissions of these chemicals must be rapidly terminated in order to stabilize and eventually reduce chlorine and bromine levels reaching the stratosphere, and in order to minimize the extent of global warming, and (3) that the highest priority must be given to developing safe substitutes for CFCs and related compounds, and to maximizing recovery, recycling, and destruction of such quantities of these chemicals as remain in use. We have called for a rapid global phase-out of these compounds, and their replacement with safe substitutes. Specifically, we have urged:

- A 30 percent reduction in emissions of CFCs, halons, and related compounds within 18 months. This is achievable by terminating the use of CFCs as aerosol propellants or by equivalent actions.

- An 85 percent reduction in emissions of such compounds within five years. We expect that this will require an 85% cut in production (which may be partially offset by programs of recovery, recycling, and destruction) and the introduction of substitute compounds. According to Dupont, the world's largest producer of CFCs, substitute compounds can be produced in volume within five years if appropriate market incentives are provided.

- A near-complete phase-out of remaining emissions within ten years. This period allows for the full penetration of alternatives and for replacement of current equipment which requires the present chemicals.

In our view, the phase-out should cover all CFCs, halons, and long-lived chlorinated solvents, although we recognize that there may be value in taking into account differences in various chemicals potency as ozone depleters.

Obviously, the phase-out could be moderated if, however unexpectedly, new scientific data eliminates cause for concern. But if the Antarctic ozone hole is linked to CFCs, or if NASA's satellite data on higher-than-expected rates of ozone depletion are confirmed, then we will be facing a global emergency. In that case the phase-out will have to take place immediately.

A major development last year was a change in industry's approach to this problem: from an almost fanatical opposition to regulation to a more moderate view that admits there is a serious environmental problem. The producers, especially Dupont, are much more optimistic about their ability to make substitutes. These substitutes however, will likely be more expensive, at least in the short run. One area of commonality between industry and environmentalists is a recognition that government incentives such as those provided by the phase-out are needed to make the substitutes viable.

In November, as you know, the State Department and EPA issued "views" on the contents of an appropriate agreement. The U.S. called for a "short-term freeze" "at or near current levels" of production of four CFCs and two halons. This would be followed by a "long-term phase-out." The position actually proposed in Geneva in December suggested a phase-down of these substances by as much as 95% over an unstated period of years.

How does the U.S. proposal measure up against the need? While the proposal is generally positive, it does not provide for feasible short-term reductions. The Nordic countries proposed to

cure this deficiency by offering an amendment to the U.S. draft that would add a short-term emissions cut of 25%. The U.S. delegation, however, has not endorsed the Nordic amendment. Also, the U.S. position should cover all ozone depleters, not just selected CFCs and the halons. Above all, everything depends on how rapidly and completely the phase-out takes place: how long is "long-term" and how far down will emissions be reduced. The vagueness of the U.S. position on these last points is worrisome.

The European Community and Japan, as you know, are our principal antagonists in the negotiations. The EC has stated that it might go along with a freeze at current level for perhaps four CFCs. Japan thus far wants to exclude one of these four, CFC-113 used in its electronics industry, from even this limited freeze. In the face of the danger to health and environment and the need to foster rapid substitution of safer substances, these proposals are grossly inadequate. At a political level, there are strong signs that some EC countries recognize this and are prepared to go beyond a freeze to actual reductions.

We believe the U.S. should bargain hard for a phase-out on a schedule no more lengthy than we have proposed. Given the generality of the U.S. position, however, we are concerned about how far the U.S. delegation will retreat and what it will settle for. Administrator Thomas has assured me that he is committed to the current phase-down proposal and that the U.S. will stick to it. There are, however, other claimants within the

Administration for control of the decision. In particular, staff of the Domestic Policy Council and the Commerce Department are positioning themselves to weaken, rather than strengthen, the U.S. proposal. The Office of Management and Budget (OMB) lurks as always in the background, although it seems to be planning to concentrate on the domestic regulatory decision.

On the domestic side, NRDC and EDF advocate a phase-out as presented above with or without an international agreement. The U.S. is alone responsible for approximately 30% of the world's CFC use; we have a responsibility to curb these emissions even if other countries lag behind. Some will say that U.S. action alone would not reduce emissions enough. Others will say that domestic industries bearing the costs of curbing emissions of CFCs and related compounds would be disadvantaged by imports from countries which do nothing. There is, however, a tool at our disposal that can protect our industries while simultaneously leveraging emission reductions from other countries and giving the U.S. the jump in the competition to bring on alternative substances, recycling techniques, etc.: The U.S. should couple a domestic phase-out with a restriction on imports of products which contain or are made with these chemicals from countries which do not carry out an equivalent phase-out program.

Such an import restriction would cover not only bulk CFCs (in which there is little trade to the U.S.) but also many finished products. Most notably, it would cover cars (whose foam seats and air conditioners contain CFCs) and computers and other

electronic equipment (whose chips were cleaned with CFC solvents). As you can plainly see, such a restriction would get the attention of other governments. Faced with the loss of major U.S. markets, few countries would decline to phase-out CFCs, a step with trivial economic and political costs in comparison. At the very least, the serious prospect of such an import restriction should improve the U.S. bargaining position in the international negotiations.

According to a recent legal opinion from the U.S. Trade Representative, such an import restriction would be completely acceptable under the GATT and related agreements, since it has a clear health and environmental justification and since it treats domestic and foreign products alike.

A domestic phase-out will also enhance U.S. competitiveness. As incentives are created by the reduced supply of conventional CFCs, U.S. industries will have the opportunity to steal a march on foreign competitors in the race to commercialize substitute products, recycling techniques, etc. Nearly all informed persons will bet that continued adverse scientific findings will compel Europe and Japan to follow our lead, if not immediately then in several years. If the U.S. acts first, our companies will be poised to export, not import, the technologies for the future.

Here again, however, we are uncertain where the EPA is headed. All options, ranging from the measures sketched out here to completely unacceptable inaction, appear to be under

consideration. Guided by experience, EPA is behaving as though it expects OMB to be a major hurdle.

Let me turn to specific steps that the Administration and the Congress should be taking now.

As for Administration, the U.S. needs first to firm up its position in the international negotiations before the February session. The U.S. should adopt the Nordic countries' amendment to its proposal and seek short-term CFC emission cuts rather than just a freeze. The State Department should work with supportive countries (e.g., Canada, the Nordic countries, Switzerland, Egypt, Brazil and Argentina) to form a unified negotiating bloc behind the U.S./Nordic proposal. Considerable opportunity exists to work with the U.S.S.R. which proposed the replacement of CFCs with safe substitutes by the year 2000.

Second, the Administration should make clear that EPA and the Department of State call the shots, not staff of the Domestic Policy Council, the Department of Commerce, or the OMB. EPA and State are the agencies Congress has charged with responsibility over CFCs in the domestic and international arenas. Their authority must not be undermined.

Third, Administrator Thomas needs to continue and step up his efforts to bring the CFC issue to the highest level of the environment ministries in other countries. His appearance at the Geneva negotiations was symbolically important in emphasizing the depth of U.S. feeling on this issue. He is reported to have had direct telephonic contacts with at least one of his ministerial

counterparts; he needs to do substantially more of this. He had planned to go to Europe in January and meet bilaterally with ministers in the key countries; this trip did not take place and reportedly has been rescheduled for April. The delay is regrettable. Now is when those countries are, or should be, reevaluating their positions. Hopefully, the delay will not sacrifice the opportunity to influence their positions before they set in concrete once again. Both EPA and State Department officials need to do the maximum to learn what other countries are thinking and planning before the next negotiating session in February. To an undesirable degree, the U.S. delegation walked into the Geneva session without a firm idea of where other countries were coming from.

Fourth, the Department of State needs to make control of these chemicals a much higher priority issue in its regular contacts with EC countries, Japan, the U.S.S.R., and others. Foreign ministers and heads of state, not just environment ministers, need to appreciate the importance of this issue to the U.S. Other countries -- especially those which sent only the lowest level representatives to Geneva -- must be persuaded to pay the issue the attention it deserves. This means that the issue must be elevated to higher levels in the State Department. Without denigrating the abilities and efforts of Mr. Negraponte and Mr. Benedick, other countries undoubtedly draw conclusions from the fact that this issue is not pressed by higher officials. The U.S. phase-out proposal should be on the agenda when

Secretary Shultz and other high State Department officials meet with their counterparts. The State Department should also be encouraging participation in the negotiations by more developing countries. They have a great deal at stake, and judging by those present in Geneva last December, they will be supportive of the U.S. position.

Fifth, the U.S. must decide to phase-out CFCs, halons, and related chemicals domestically and to institute the proposed import restriction. EPA should formally propose these actions in May and adopt them in November. The State Department should let this course of action be known to other countries as soon as possible, even before the February session in Vienna. The sooner and more forcefully these policies are instituted, the better will be the chances for an good international accord. Even without formal agreement these U.S. policies will leverage other governments to follow suit.

As for the Congress, NRDC and EDF applaud this committee for undertaking oversight of these activities. We look forward to continued close scrutiny of these activities by committees in both Houses. We urge you to press the Administration for specific commitments to take the steps outlined above.

Second, we urge the enactment of legislation embodying the domestic phase-out and import restriction. Given the cross-currents within the Administration, a good outcome from the EPA regulatory process cannot be depended on. The introduction and passage of such legislation would strongly enhance the U.S.

bargaining position in the international negotiations. Failing an agreement, such legislation would make major emission reductions here while leveraging cooperation by other countries on a bilateral basis. The phase-out, coupled with the import restriction to leverage cooperation abroad, should be embodied in U.S. law at the earliest possible time.

I will be happy to answer any questions you may have.

OZONE DEPLETION AND CLIMATE CHANGE: A STATEMENT ON CHLOROFLUOROCARBONS AND RELATED COMPOUNDS BY THE INTERNATIONAL ENVIRONMENTAL COMMUNITY

The biosphere of the planet is gravely threatened by emissions into the atmosphere of chlorofluorocarbons (CFCs) and other long-lived industrial compounds containing chlorine or bromine. If unchecked, these gases will deplete the protective stratospheric ozone layer and contribute to global temperature increases with disastrous consequences for human health and environment world-wide. Citizens, governments, and industries world-wide are now recognizing the need to control emissions of CFCs and related gases.

The principal compounds of concern include six chlorofluorocarbons (CFC-11, CFC-12, CFC-22, CFC-113, CFC-114, and CFC-115), three chlorinated solvents (carbon tetrachloride, methyl chloroform, and methylene chloride), and two bromine-containing halons (Halon-1211 and Halon-1301).

Under the 1985 Vienna Convention for the Protection of the Ozone Layer, national representatives will begin negotiations in Geneva in December 1986 on an international agreement to limit emissions of these compounds. To focus attention on the need for sharp and rapid emission reductions, the undersigned organizations present this statement on ozone depletion and climate change from CFCs and related compounds. Based on review of the most up-to-date scientific research, we conclude as follows:

1. Continued emissions of CFCs and related compounds gravely imperil human health and critical ecosystems of the planet. The risk of damage to human health and the environment outweighs the benefits of using these compounds.

2. Any level of stratospheric ozone depletion or global warming is undesirable. An experiment of global scale is being conducted on the earth's atmosphere without a full understanding of the consequences. This is unacceptable.

3. In order to stabilize and eventually reduce chlorine and bromine levels reaching the stratosphere, and in order to minimize the extent of global warming, emissions of these compounds must be rapidly terminated.

4. The highest priority must be given to instituting programs of recycling, recovery, and destruction for CFCs and related compounds and to developing and deploying safe substitutes for ozone-depleting and climate-changing chemicals.

To protect human health and the environment world-wide, we call for a rapid phase-out of CFCs and the other compounds listed in this statement. Specifically, we call for:

- o A 30 percent reduction in emissions of the listed compounds within 18 months. This is achievable by terminating the use of CFCs as aerosol propellants or by other equivalent actions. Countries which do not have bans on the use of CFCs as aerosol propellants should make proportionally larger reductions.

- o An 85 percent reduction in emissions of the listed compounds within five years. We expect that this will require an 85% cut in production (which may be partially offset by programs of recovery, recycling, and destruction) and the introduction of substitute compounds. According to Dupont, the world's largest producer of CFCs, it can produce substitute compounds in volume within five years.

- o A near-complete phase-out within ten years, which could be modified in light of developing scientific findings. This period allows for full penetration of alternatives, and for replacement of current equipment which requires the present chemicals.

This timetable would allow an orderly transition to products and processes which do not endanger human health or the global environment.

New scientific findings, however, may require even faster emission reductions:

1. Real rates of ozone depletion may in fact be surpassing all model projections. Satellite data from the U.S. National Aeronautics and Space Administration (NASA), now under careful review, indicate that large global ozone reductions may have occurred over the past several years. The measured ozone losses exceed model projections by as much as eight times.

2. Large losses in ozone have been recorded over Antarctica in springtime for nearly a decade. Scientists investigating the Antarctic ozone losses in October 1986 have reported that proposed explanations related to solar cycles or dynamical processes are unlikely. Chemical processes, possibly involving chlorine, are more likely to be responsible. An ozone hole over the arctic also has been reported.

These global and polar ozone losses may be related to CFCs. They are not predicted by current atmospheric science models. If their relationship to CFCs is confirmed, then drastic, immediate emission reductions will be necessary.

BACKGROUND

Chlorofluorocarbons and other long-lived chlorine- and bromine-containing compounds have a wide range of industrial and commercial applications, including refrigeration, insulation, aerosol propellants, solvents, and fire extinguishers. In all such applications, the compounds are released into the air, either immediately or on a delayed basis.

Because these compounds are so stable, they can remain unaltered in the atmosphere for as long as 100 years or more. Over time, they migrate into the upper atmosphere (the stratosphere), which contains the earth's protective ozone shield. There these compounds are decomposed by ultraviolet radiation. The chlorine or bromine they contain then catalyzes a chain reaction in which ozone is destroyed.

Ozone depletion allows more ultraviolet radiation to reach ground level, in particular radiation in the wavelengths known as UV-B. This radiation is highly dangerous because life on earth is delicately tuned to the wavelengths and intensity of solar radiation reaching ground levels.

CFCs and related compounds also absorb infrared radiation from the earth's surface, contributing to a warming of the climate through a phenomenon known as the "greenhouse effect." On a molecule-for-molecule basis, CFCs absorb 10,000 times more infrared radiation than carbon dioxide. Global warming induced by these compounds will produce a host of disastrous climatic changes ranging from sharply higher temperatures to world-wide alterations in storm and precipitation patterns.

The health and environmental impacts of these changes may be summarized as follows.

HUMAN HEALTH EFFECTS

Higher levels of UV-B radiation will sharply increase rates of nonmelanoma skin cancer and probably malignant melanoma as well. Millions of additional cases of skin cancer will result between 1980 and 2025 in the United States alone if CFC emissions continue to grow as projected. Eye damage, including cataracts and retinal damage, will also occur. Immune system responses may also be suppressed, causing increases in rates of herpes, hepatitis, and other diseases.

Increased UV-B radiation will also cause higher levels of ozone "smog" in urban atmospheres. Approximately one person in five is especially sensitive to ozone smog levels already common in urban areas.

Climate change caused by these compounds will also have severe effects upon health. Urban death rates will rise as the number and severity of summertime heat waves increase. Higher sea level and increased storm flooding may cause large losses of life and property.

AGRICULTURAL AND TERRESTRIAL ECOSYSTEM EFFECTS

Increased UV-B radiation will also have grave consequences for vegetation. Important cereal grains and fiber crops have shown sensitivity to UV-B radiation. Recent field studies have shown a 20% reduction in soybean yield from a simulated 25% ozone depletion. Increased production of ground-level ozone smog will damage plants. Forests and other natural systems will also be damaged.

Climate change will cause marked changes in the distribution of precipitation and frequency of severe weather. Changes in rainfall patterns will have dramatic impacts on crop yields. Economic and social disruption could result from regional shifts in agricultural patterns.

AQUATIC EFFECTS

Increased UV-B radiation may cause the collapse of complex food chains in aquatic environments. Reduced productivity occurs among phytoplankton, an important early link in the food chain, when exposed to increased UV-B radiation. Many higher-order life forms in aquatic systems are vulnerable in their larval stage. Reductions in commercially valuable fish catches can be expected due to the reduction in food supplies at the bottom of the food chain.

SEA LEVEL RISE AND PROPERTY DAMAGE

Climate warming will cause sea level to rise dramatically -- approximately one meter by the middle of the next century -- causing enormous economic damage to coastal property. Water would inundate 11.5% of Bangladesh's land area where 8 million people now live. Sea level rise will also cause salt water intrusion into freshwater resources, widespread destruction of wetlands by flooding, accelerated coastal erosion, and increased inland flooding during storms.

UV-B radiation also damages man-made materials. In the U.S. alone, damage to materials made of just one plastic (polyvinyl chloride) has been estimated to range between 10 and 27 million dollars per year if CFC emissions continue to grow as projected.

BROADER ENVIRONMENTAL EFFECTS

As severe as these consequences are, they do not include damage that will occur to wildlands and wildlife. Forests, wetlands, and wildlife dependent on them have very little ability to adapt to increasingly hostile radiation and climate.

THE NEED FOR RAPID EMISSION REDUCTIONS

That CFCs and related compounds endanger human health and the environment has been known since 1974, when their role in stratospheric ozone depletion was discovered. Four important findings, however, now demonstrate the need for rapid action to sharply reduce emissions of these compounds.

1. Until this year, nearly all projections of ozone depletion rates were made with one-dimensional atmospheric models. These models give a global average figure for ozone depletion, irrespective of latitude. Newer two-dimensional models, however, project substantially higher ozone depletion rates in northern and southern latitudes away from the equator. For example, under conditions in which "1-D" models project a one or two percent ozone loss on a global average basis, "2-D" models show several times greater levels of depletion at the latitudes of northern Europe and North America (50-60 degrees north). Ozone depletion of this magnitude is regarded as exceptionally dangerous.

2. Vertical redistribution of ozone may be as important as latitudinal changes. Even as ozone is depleted overall, ozone increases may occur at some altitudes. The atmospheric balance of heat and moisture may be markedly changed by such vertical

ozone shifts, and these changes may lead to large-scale climate modification.

3. The concentration of chlorine in the stratosphere will continue to increase -- and so will ozone depletion -- even if CFC emissions do not increase. To rapidly stabilize chlorine concentrations in the stratosphere, current emission rates for CFC-11 and CFC-12 would have to be cut by approximately 85 percent.

4. New attention has been paid to the role of CFCs and related compounds in climate warming. Recent studies indicate that approximately one-sixth of the total man-made atmospheric warming to which our planet is now committed will be due to CFCs. With a total warming of up to six degrees Fahrenheit (approximately three degrees Centigrade) possible by the year 2030, every possible step to limit the build-up of greenhouse gases is necessary.

We recognize that it may be appropriate to treat CFC-22 on a different basis from other compounds listed in this statement, while substitutes are being developed and deployed. While CFC-22 is still an ozone depleter and infrared absorber, it is substantially less potent than the other listed compounds. Because it does deplete ozone, however, CFC-22 should only be used on an interim basis until better substitutes are available.

The undersigned organizations call on the governments negotiating in Geneva to avert a global environmental tragedy by adopting an agreement which accomplishes these objectives.

December 2, 1986

European Environmental Bureau
Friends of the Earth International
Natural Resources Defense Council
Environmental Defense Fund
Swedish Society for the Conservation of Nature

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